AL.2.1985-999

OCT - 2 1986

REPORT #
RRTAC 85-1

Revegetation Methods For Alberta's Mountains And Foothills

Heritage Fund

Alberta
LAND CONSERVATION AND
RECLAMATION COUNCIL
Reclamation Research
Technical Advisory Committee

DDN 5820848

REPORT #RRTAC 85-1

WORKSHOP PROCEEDINGS

Revegetation Methods For Alberta's Mountains & Foothills

30 April - 1 May 1984

EDMONTON, Alberta

P.F. Ziemkiewicz
Editor

This Workshop was organized by the

Reclamation Research Technical Advisory Committee

of the

Alberta Land Conservation & Reclamation Council

Revegetation Methods
for the
Mountains and Foothills
Organized by the
Reclamation Research Technical
Advisory Committee

Date: April 30-May 1, 1984
Place: EDMONTON, Alberta

TABLE OF CONTENTS **PAGE**

INTRODUCTION - P.F. Ziemkiewicz 1

SUMMARY - P.F. Ziemkiewicz 2

Performance of Native Grasses and cultivated Legumes and Grasses on Land Disturbances in the Eastern Slope
- S.K. Takyi, R. Islam 4

Bow Valley Revegetation Trails, Banff National Park
- D.G. Walker, G. Harrison 33

Effects of Topsoiling, Maintenance Fertilization and Species Selection on Long-Term Revegetation Success
- P.F. Ziemkiewicz 50

Maintenance Fertilization of a Revegetated Subalpine Coal Mine Spoil
- S.K. Takyi, R. Islam 78

Revegetation of Oil & Gas Disturbances - Seed Mixes, Fertilizers and Application Methods
- P.F. Ziemkiewicz 90

Reclamation Research at No. 8 and No. 9 Mines, Grande Cache, Alberta
- T. Macyk, B. Skirrow 101

Plant Cover Establishment on a Severe Site in the Sub-Alpine
- S.K. Takyi 112

TABLE OF CONTENTS **PAGE**

Natural Vegetation and Ecology of Abandoned Coal Mined Land at Sterco-Coal Valley, Alberta
- W.B. Russell 145

The Role of Topsoil, Fertilizers and Companion Crops in Revegetation of Sites in the Sub-Alpine
- S.K. Takyi 163

The Establishment and Maintenance of Plant Cover on Disturbances in the National Parks
- G. Harrison 192

Rehabilitation of Oil and Salt Water Spill Sites
- D. Blackmore 204

Pre-germination Treatments for selected Woody Plant Species Native to the Eastern Slopes
- P. King, G. Grainger, A. Straka 227

Reforestation Studies at The Judy Creek Test Mine - Overview and Preliminary Results
- A. Kennedy 270

Methodology and Initial Results of the Bryan Mountain Reclamation Test Plots
- D. Kittleson 301

Woody Plant Demonstrations and Trials on Disturbances in the Eastern Slopes
- P. King 318

Current Research on Seedling Growth at Obed Marsh
- T.A.B. Adamson 353

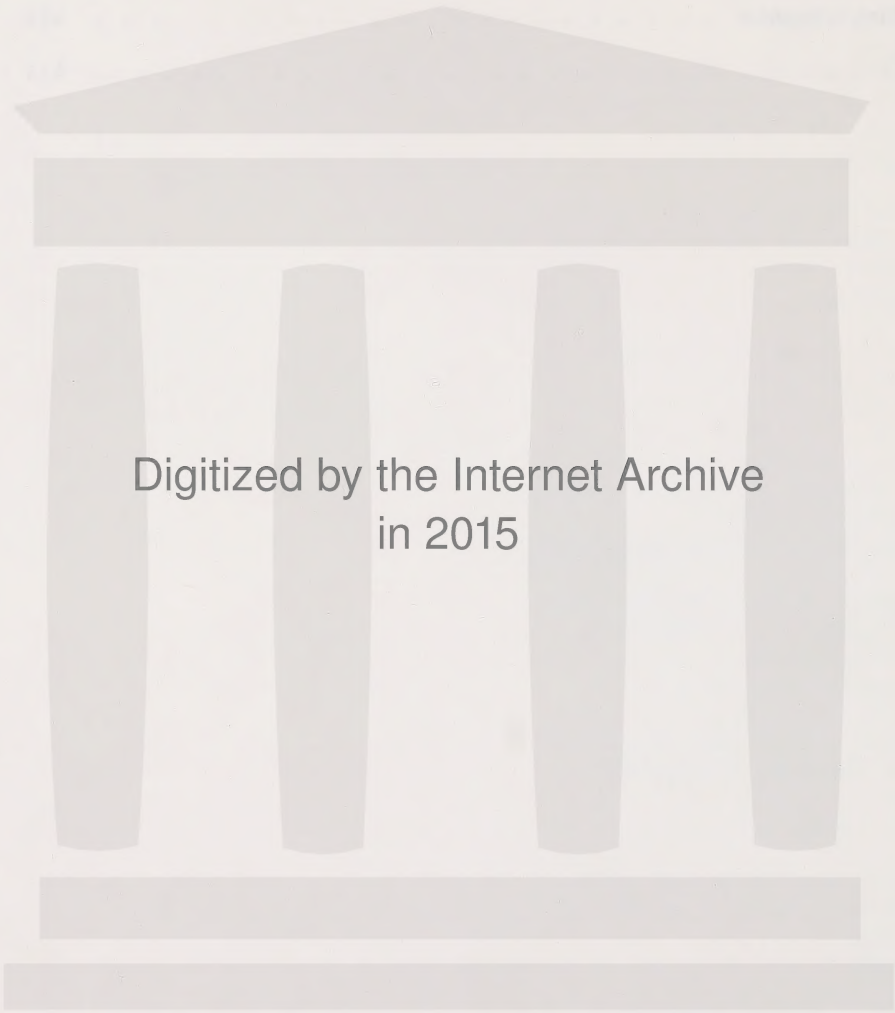
Revegetation Planning for Wildlife and Forestry
- R. Millson, T. Bondy 369

TABLE OF CONTENTS **PAGE**

Wildlife End Uses in Reclamation:
Concepts and Opportunities
- J. Green, K. Yonge 384

List of Participants 411

Agenda 415



Digitized by the Internet Archive
in 2015

https://archive.org/details/revegetationmeth00reve

ALBERTA'S RECLAMATION RESEARCH PROGRAM

The regulation of surface disturbances in Alberta is the responsibility of the Land Conservation and Reclamation Council. The Council executive consists of a chairman from the Department of the Environment and two deputy chairmen from the Department of Energy and Natural Resources. Among other functions, the Council oversees programs for reclamation of abandoned disturbances and reclamation research. The Reclamation Research Program was established to provide answers to the many practical questions which arise in reclamation. Funds for implementing both the operational and research programs are drawn from Alberta's Heritage Savings Trust Fund.

To assist in technical matters related to the development and administration of the research program the Council appointed the Reclamation Research Technical Advisory Committe (RRTAC). The Committee first met in March, 1978 and consists of eight members representing the Alberta Departments of Agriculture, Energy and Natural Resources, Environment and the Alberta Research Council. The Committee meets regularly to update research priorities, review solicited and unsolicited research proposals, arrange workshops and otherwise act as a referral and coordinating body for Reclamation Research.

Additional information on the Reclamation Research Program may be obtained by contacting:

Dr. P.F. Ziemkiewicz, Chairman
Reclamation Research Technical Advisory Committee
Alberta Energy & Natural Resources
2nd Floor Pacific Plaza
10909 Jasper Avenue
EDMONTON, Alberta
T5J 3M8

Phone No. 427-8042

This Report may be cited as:

Ziemkiewicz, P.F. 1985 (Ed.) Revegetation Methods for Alberta's Mountains & Foothills, Proceedings of a Workshop held 30 April - 1 May 1984, Edmonton Alberta, Alberta Land Conservation & Reclamation Council Report #RRTAC 85-1

RECLAMATION RESEARCH REPORTS

			REPORT NO.
*1.	TITLE:	The Role of Organic Compounds in Salinization of Plains Coal Mining Sites.	RRTAC 80-3
	AUTHOR(S):	N.S.C. Cameron et al.	
	DESCRIPTION:	This is a literature review of the chemistry of sodic mine spoil and the changes expected to occur in groundwater. 46 p.	
*2.	TITLE:	Proceedings: Workshop on Reconstruction of Forest Soils in Reclamation.	RRTAC 80-4
	AUTHOR(S):	P.F. Ziemkiewicz, S.K. Takyi, H.F. Regier	
	DESCRIPTION:	Experts in the Field of Forestry and Forest Soils Report on Research relevant to Forest Soil Reconstruction and discuss the most effective means of restoring forestry capability of mined lands. 160 p.	
*3.	TITLE:	Manual of Plant Species Suitability for Reclamation in Alberta, 2 Vols.	RRTAC 80-5
	AUTHOR(S):	L.E. Watson, R.W. Parker, P.F. Polster	
	DESCRIPTION:	Forty-three grass, fourteen forb and thirty-four shrub and tree species are assessed in terms of their fitness for use in Reclamation. Range Maps, Growth Habit, Propagation, Tolerances and Availability. 541 p.	
*4	TITLE:	1980 Survey of Reclamation Activities in Alberta	RRTAC 81-2
	AUTHOR(S):	D.G. Walker, R.L. Rothwell	
	DESCRIPTION:	This survey is an update of the original Report conducted in 1976 on Reclamation Activities in Alberta, includes Research and Operational Reclamation, locations, personnel etc. 76 p.	

Available from: Publication Services
Queen's Printer
11510 Kingsway Avenue
EDMONTON, Alberta T5G 2Y5

* A $5.00 fee is charged for handling and postage.
** A $20.00 fee is charged for handling and postage.

Please make cheque payable to: "Provincial Treasurer of Alberta"

*5.	TITLE:	Proceedings: Workshop on Coal Ash and Reclamation.	RRTAC 81-3
	AUTHOR(S):	P.F. Ziemkiewicz, R. Stien, R. Leitch, G. Lutwick	
	DESCRIPTION:	Presents nine technical papers on the Chemical, Physical and Engineering Properties of Alberta Fly and Bottom Ashes, Revegetation of Ash Disposal Sites and Use of Ash as a Soil Amendment. Workshop discussions and summaries are also included.	
*6.	TITLE:	Land Surface Reclamation: An International Bibliography. 2 Vols.	RRTAC 82-1
	AUTHOR(S):	H.P. Sims, C.B. Powter	
	DESCRIPTION:	Literature pertinent to Reclamation in Alberta is listed in Vol. 1 and is also on the University of Alberta Computing System. The Keyword Index and Computer Access Manual comprises Vol. 2. 292 p.	
*7.	TITLE:	A Bibliography of Baseline Studies in Alberta: Soils Geology, Hydrology and Groundwater.	RRTAC 82-2
	AUTHOR(S):	C.B. Powter, H.P. Sims	
	DESCRIPTION:	This Bibliography provides baseline information for persons involved in Reclamation Research or in the Preparation of Environmental Impact Assessments. Materials, up to date as of Dec. 1981 are available from the Alberta Environmental Library. 97 p.	
*8	TITLE:	Soil Reconstruction Design for Reclamation of Oil Sand Tailings.	RRTAC 83-1
	AUTHOR(S):	Monenco Consultants Ltd.	
	DESCRIPTION:	Volumes of Peat and Clay required to amend Oil Sand Solid Tailings were estimated based on existing literature. Separate soil prescriptions were made for Spruce, Jack Pine and Herbaceous cover types. The estimates form the basis of recently initiated field trials. 185 p.	

RECLAMATION RESEARCH REPORTS Cont'd.

			REPORT NO.
*9.	TITLE:	Evaluation of Pipeline Reclamation Practices on Agricultural Lands in Alberta.	RRTAC 83-3
	AUTHOR(S):	Hardy Associates (1978) Ltd.	
	DESCRIPTION:	Available information on Pipeline Reclamation practices was reviewed. A field survey was then conducted to determine the effects of pipe size, age, soil type construction method etc. on resulting crop reproduction. 205 p.	
*10.	TITLE:	Proceedings: Effects of Coal Mining on Eastern Slopes Hydrology	RRTAC 83-4
	AUTHOR(S):	P.F. Ziemkiewicz	
	DESCRIPTION:	Technical Papers are presented dealing with the impacts of Mining on Mountain Watersheds, their flow characteristics and resulting water quality. Mitigative measures and Research priorities were also discussed. 123 p.	
*11.	TITLE:	Woody Plant Establishment and Management for Oil Sands Mine Reclamation.	RRTAC 83-5
	AUTHOR(S):	Techman Engineering Ltd.	
	DESCRIPTION:	This is a review and analysis of information on planting stock quality, rearing site preparation, planting and procedures necessary to ensuring survival of trees and shrubs in oil sand reclamation. 124 p.	
**12.	TITLE:	Land Surface Reclamation: A Review of International Literature. 2 Vols.	RRTAC 84-1
	AUTHOR(S):	H.P. Sims, C.B. Powter, J.A. Campbell	
	DESCRIPTION:	Nearly all topics of interest to Reclamation includes Mining Methods to Soil Amendments, Revegetation, Propagation and Toxic Materials are reviewed in light of the International Literature. 1549 p.	

*13. TITLE: Propagation Study: Use of Trees and Shrubs for Oil Sand Reclamation — RRTAC 84-2

AUTHOR(S): Techman Engineering Ltd.

DESCRIPTION: This Report evaluates and summarizes all available published and unpublished information on large-scale propagation methods for shrubs and trees to be used in Oil Sand Reclamation.

*14. TITLE: Soil Microbiology in Land Reclamation. 2 Vols. — RRTAC 84-4

AUTHOR(S): D. Parkinson, R.M. Danielson, C. Griffiths, S. Visser and J.C. Zak

DESCRIPTION: This is a collection of five Reports dealing with Reestablishment of Fungal Decomposers and Mycorrhizal Symbionts in various amended spoil types. 676 p.

*15. TITLE: Proceedings: Revegetation Methods for Alberta's Mountains and Foothills — RRTAC 85-1

AUTHOR(S): P.F. Ziemkiewicz

DESCRIPTION: Results of long-term experiments and field experience on Species Selection, Fertilization, Reforestation, Topsoiling Shrub Propagation and Establishment are presented.

*16. TITLE: Reclamation Research Annual Report - 1984 — RRTAC 85-2

AUTHOR(S): P.F. Ziemkiewicz

DESCRIPTION: This Report details the Reclamation Research Program indicating priorities, descriptions of each Research Project, researchers, results and expenditures. 29 p.

INTRODUCTION

Over the past decade most Reclamation Research in the eastern slopes has sought methods for establishing a grass legume cover on mine spoil. This was a logical approach since most operational Reclamation Programs were initially faced with the immediate requirement to control soil erosion. So a considerable amount of information has accumulated for the establishment or revegetation phase based on research and operational experience. This information consists mainly of scattered individual project results and a great deal of knowledge acquired by individuals with practical experience.

On April 30 and May 1, 1984 the Reclamation and Research Technical Advisory Committee organized a workshop with these objectives in mind:

1) to pool this information together,

2) present it and subject it to the scrutiny of knowledgeable individuals in the field.

This workshop pertained to the establishment phase from initial seeding or planting to roughly the next five years when further management inputs are no longer necessary.

Participants in the workshop included Government and Industry staff as well as Researchers. This presented a good opportunity for all concerned parties to discuss their ideas among knowledgeable peers. The intent was to find out whether there was agreement on such topics as: Species Selection, Fertilization Management, Establishment Methods Topsoiling and where possible, long term vegetation trends and stability. Other items which were discussed included introduction of trees and shrubs on reclaimed land and natural invasion of plants. Although woody plant establishment is still largely in the research stage, some results were available and relevant information from reforestation work was examined.

Paul F. Ziemkiewicz

SUMMARY

This workshop was unusual in that it generated many conclusions. Moreover many of the conclusions were in agreement though achieved through very different research pathways and approaches.

The following summarizes the major conclusions based on workshop presentations, discussion and individual conversation.

The agronomic species identified in the papers perform well in most subalpine reclamation. However, in alpine and in severe subalpine conditions the identified native species were superior.

The keys to long-term maintenance and survival of established herbaceous cover are: 1) regeneration and 2) nutrient supply. Regeneration is achieved by establishing species which will propagate by seed on rhizome.

Both native and agronomic species with strong regeneration were identified. Adequate nutrient supply is achieved by replacing topsoil or by establishing a strong legume component in the herbaceous cover. Fertilization is necessary to achieve establishment and rapid cover development. Fertilization, however, should not be continued for more than three years. It appears that over-fertilization has a negative effect on the legume component. Agronomic grasses were found in some instances to inhibit the invasion of native species e.g. in pure stands of smooth bromegrass. However, on sites dominated by other agronomic grasses (fescues) native invasion was quite high. Withdrawal of maintenance fertilization encourages native invasion.

Maintenance of a strong legume component on revegetated areas can pose a problem. Alfalfa grows well and persists well but it does not regenerate itself to any significant extent. Only alsike clover reseeds itself effectively though only to the upper subalpine elevations. Cicer milkvetch persists well and spreads by rhizomes. Other commercial legumes are generally short-lived and ineffective propagators in the mountains. Legume stands are also susceptible to damage from wildlife grazing and to winterkill on areas or in years with thin snow cover.

There was no consensus on the issue of whether tree and shrub seedlings should be planted into grass cover or whether plantings should be made on bare ground. It was clear, however, that tree and shrub seedlings will do poorly in dense grass and that the herbaceous cover should not be fertilized for several years prior to and after planting. Planting in a thin grass cover has the advantage of reducing wind exposure, trapping snow and minimizing soil erosion. The disadvantages include moisture and nutrient competition as well as rodent habitat. The advantages and

disadvantages must be assessed on a site-by-site basis. Regarding the preferred planting stock for reclamation, there was no resolution of the containerized vs. bare root controversy. It is probably fair to generalize to the extent that containerized stock is easier to handle while, if properly handled, bare root stock grows better.

Plant cover development on unreclaimed mine sites is slow and ineffective. On mined sites which had been left to revegetate naturally for 20 years plant cover was strongly associated with slope position. Median total plant cover ranged from 0.3% on upper slopes to 6.7% at the bases of slopes. A few sites with up to 50% cover were reported but these were dominated by the agronomic grasses smooth brome grass and red fescue. These apparently resulted from earler seeding efforts by the Alberta Forest Service.

Site scarification after logging is a common and successful reforestation technique in Alberta. Scarification is accomplished by dragging a variety of equipment over the logged area to mix the duff, slash and mineral soil materials. Among other benefits this breaks up the duff layer so that seedlings contact mineral soil more quickly. On unscarified sites seedlings are prone to dry out where planted into thick duff layers. The implication for reclamation is that organic soil amendments should be thin enough to allow incorporation with mineral soil.

The workshop concluded with a wildlife-orientation to ensure that this oft-neglected topic received at least some attention. The participants, whose careers are spent watching wild animals eat everything they plant, listened politely and perhaps skeptically at first but were finally compelled to the conviction that Reclamation, Forestry and Wildlife goals were not only compatible but almost symbiotic.

Paul F. Ziemkiewicz

PERFORMANCE OF NATIVE GRASSES AND CULTIVATED LEGUMES AND GRASSES ON DISTURBANCES IN THE EASTERN SLOPES OF THE ROCKIES[1]

S.K. Takyi and R.M. Islam

Alberta Forest Service

Department of Energy and Natural Resources

Edmonton

INTRODUCTION

The Eastern Slopes of the Canadian Rocky Mountains include the alpine and subalpine ecoregions in Alberta. The area is characterized by cold winters, short cool summers and fewer than 60 frost-free days a year. These conditions result in a difficult task in the revegetation and rehabilitation of land disturbances by any reclamation standards.

Several abandoned, existing and planned strip coal mines are located in the Eastern Slopes, and some of the mines border the subalpine region. Land disturbances associated with other resource extraction activities are to be found extending into the alpine region.

---

[1]This paper has been published as Energy and Natural Resources Technical Report Number: T/68.

Natural regeneration on subalpine and alpine disturbances is a slow process because of the harsh physical environment of the eco-regions. The establishment of a protective plant cover with grasses and legumes is a primary technique to stabilize disturbed land surface and control erosion. The ability of plant species to adapt to a site is also an important requirement for successful revegetation. O.S. Aamodt[1] wrote: "Nature did a superb job with the grasses and legumes, spreading them over much of the earth, adapting them to an immense range of climates. They would still be there to feed our flocks and herds and to hold and build the soil if there were no other crop plants whatever in the world." We recognize the importance of grasses when we review the status of reclamation in the alpine and subalpine regions of Alberta. The question which comes to mind is, where would we be without grasses and legumes in the reclamation of land disturbances in the mountains and foothills? This paper is about the adaptability of grasses and legumes; which species thrive best on land disturbances in Alberta's high elevation environments.

BRIEF SITE DESCRIPTION AND METHODS

Series of demonstration plots with various native grasses and cultivated grasses and legumes were established between 1975 and 1977 at different locations on land disturbances across the Eastern Slopes to aid in the choice of suitable species for the revegetation of land disturbances.

---

[1]Formerly head agronomist - in-charge, Division of Forage Crops and Diseases, Bureau of Plant Industry. In: "Climate and Man," 1941 Yearbook of Agriculture, U.S.D.A.

In all the studies the choice of species and varieties was largely dictated by previous operational experiences gained in the area, and by the availability of seeds, especially of the native grasses. The locations of the demonstration planting and the adaptability trials are given in Figure 1 and Table 1. Nearly all of the sites are associated with coal mining. Several people have been involved in the studies discussed in this paper.

A. Demonstration Plantings

1. Tent Mountain

The study site is the Coleman Collieries Ltd. surface mine at Tent Mountain in the extreme southwestern corner of the province (Table 1). The site has a northern exposure with a 25° slope and is at an elevation of 2 133 m ASL. The disturbed overburden on which the planting was carried out is low in available nitrogen and phosphorus and is slightly acid in reaction. In the fall of 1975, 26 cultivated grasses and four legumes and three seed mixtures were planted on plots at the site. Seed was broadcast by hand at a rate of 10 762 seeds/m^2 and fertilized by hand to provide 112 kg N, 67 kg P and 34 kg K/ha.

2. Nine Locations in the Eastern Slopes (Adanac, Tent Mountain, Caw Creek Ridge, Luscar, Nordegg, Lovett Tower, Bighorn Dam, Racehorse Creek and Grassy Mountain)

During 1975 and 1976 several plantings of containerized native grass seedlings, in plots at different locations in the Eastern slopes

FIGURE 1

DEMONSTRATION PLANTINGS AND TRIAL LOCATIONS IN THE EASTERN SLOPES

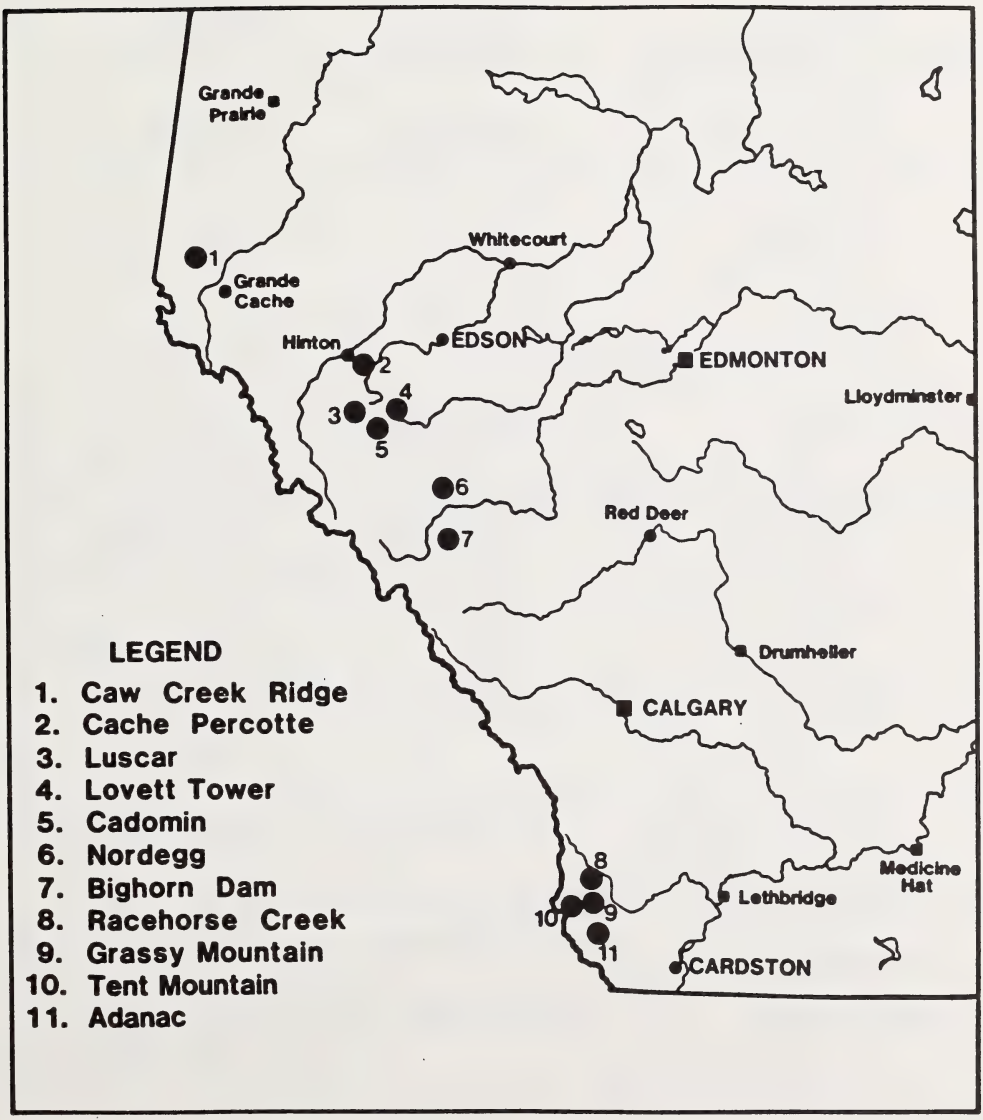


Table 1

LOCATIONS AND DISTURBANCE TYPES FOR
THE DEMONSTRATION PLANTINGS AND TRIALS
IN THE EASTERN SLOPES

Location	Ecoregion	Disturbance Type
Adanac, 2 133 m Sec 25-6-4-W5M	Subalpine to Alpine	Open-Pit Coal Mine
Tent Mountain, 2 133 m Sec 14-7-6-W5M	Subalpine to Alpine	Open-Pit Coal Mine
Caw Creek Ridge, 1 981 m 58-10-W6M	Subalpine	Coal Exploration
Luscar, 1 737 m Sec 22 -47-24-W5M	Subalpine	Open-Pit Coal Mine
Nordegg, 1 676 m Sec 14-40-15-W5M	Subalpine to Boreal Upland	Coal Exploration
Lovett Tower Road, 1 372 m Sec 16-47-10-W5M	Subalpine to Boreal Upland	Open-Pit Coal Mine
Bighorn Dam, 1 341 m Sec 35-38-17-W5M	Boreal Upland	Dam Construction
Racehorse Creek, 1 981 m Sec 7-10-4-W5M	Subalpine	Open-Pit Coal Mine
Grassy Mountain, 1 829 m Sec 1-9-4-W5M	Subalpine	Open-Pit Coal Mine
Cache Percotte, 1 311 m Sec 8-51-24-W5M	Boreal Foothills	Borrow Pit
Cadomin, 1 675 m Sec 32-46-23-W5M	Subalpine	Open-Pit Coal Mine

(Table 1), were carried out with some assistance from the Genetics Department, University of Alberta. Seeds planted were collected from different altitudinal locations throughout the Eastern Slopes. In both years, the plantings were carried out in late July and early August.

3. Cache Percotte

The Cache Percotte planting site is a borrow pit at an elevation of 1 311 m; near Hinton (Table 1). It is a well-drained site. Fifteen-week-old containerized seedlings of 17 native grass species were planted in July, 1977.

B. Adaptability Trials

1. Tent Mountain

This site is the same as described under the demonstration plantings and as shown in Table 1.

a. Cultivated Grasses and Legumes. In June 1977, two identical trials, one on disturbed overburden and the other on the overburden top-dressed with 7.5 to 10 cm of a mineral soil, were established to evaluate the performance of 16 cultivated grasses and eight cultivated legumes on the site. The plots were laid out in a randomized complete block design with three replications. The seeding rate of each species provided 1,075 seeds/m^2. All legume seeds were inoculated at the time of seeding. The trials were not fertilized.

b. Native Grasses. In September 1976, a set of trials was established on overburden to evaluate the performance of several native grasses and to compare them with two cultivated species. Tomm (1982) has described the methods of establishment and the experimental design.

2. Cadomin

The study site is an abandoned strip coal mine located in the west-central part of the province near Cadomin (Table 1). The site and the properties of the spoil and overburden are described elsewhere in these proceedings by S.K. Takyi. In June of 1978, the trials were established on overburden topdressed with mineral soil to evaluate the performances of (i) nine cultivated grass and legume species, and a grass-legume mixture, and (ii) 13 native and two cultivated grasses.

a. Cultivated Grasses and Legumes. The trial was established on spoil topdressed with 20 cm of mineral soil. A randomized complete block design was used with four replications. Seed was applied by hand at a rate of 60 kg/ha. The grass plots were hand fertilized with 60-30-62 kg/ha of N, P and K, respectively, and the legume plots with 20-30-62 kg/ha of N, P and K, respectively, at the time of establishment of the trials. The legumes were inoculated with the appropriate inoculant prior to seeding. The plots received maintenance fertilization annually until the 1981 growing season. No fertilizers were applied in 1982 and 1983.

b. Native Grasses. The trial was established on overburden topdressed with 20 cm of the same mineral soil as was used in the cultivated species trial. A randomized complete block design with four replications was

used. Each species was seeded to provide 5 000 seeds per square metre. All plots were fertilized by hand to provide 71-50-65 kg/ha of N, P and K, respectively. The plots received fertilizers annually at maintenance rates upto and including the 1981 growing season.

RESULTS

Demonstration Plantings for Adaptability Evaluation

Cultivated Grasses and Legumes

The species seeded in the fall of 1975 at Tent Mountain, except the legumes, had high germination rates in the first season. Most of the species, with the exception of the legumes, produced considerable levels of plant cover by the end of the first season (1976) of growth (Table 2). The poor plant cover in the legume plots was perhaps the result of winterkill of the germinants of the previous fall. Several of the plots were lost because of slope failure in 1977 and 1978. Plant cover improved in the grasses in 1977 but the legumes died out. As expected, plant cover in the grasses diminished in the third season (in the plots which were not affected by the slope failure) because there was no maintenance fertilization of the plots. Of the species remaining in 1978, the crested wheatgrasses, sheep fescue, Kentucky bluegrass and red top were the species which still provided adequate plant cover. The red top gave the highest dry matter yield among the species remaining in 1978.

Table 2
PERCENT PLANT COVER AND DRY MATTER PRODUCTION
OF CULTIVATED GRASSES AND LEGUMES SEEDED
AT TENT MOUNTAIN IN THE FALL OF 1975

Species[1]	Plant Cover, %			Dry Matter, kg/ha
	1976	1977	1978	1978
Thickspike wheatgrass	25	20	16	1334
Crested wheatgrass - Nordan	50	30	50	1252
Crested wheatgrass - Fairway	40	50	28	1679
Sheep fescue	40	65	32	658
Red fescue - Reptan	25	20	*	*
Red fescue - Boreal	20	60	*	*
Red fescue - Arctared	40	33	25	1396
Timothy - Agmot	20	40	*	*
Timothy	20	20	*	*
Canada bluegrass	50	44	*	*
Kentucky bluegrass - Nugget	40	60	*	*
Kentucky bluegrass - Troy	50	80	34	1125
Kentucky bluegrass - Draylan	20	27	*	*
Meadow foxtail	10	23	15	746
Meadow foxtail - Garrison	50	27	15	412
Redtop	95	50	35	3924
Redtop - Emerald	50	83	*	*
Russian wild ryegrass	25	38	*	*
Orchardgrass - Tardus	50	42	*	*
Orchardgrass	40	27	11	525
Bromegrass - Manchar	30	59	22	803
Birdsfoot trefoil	1	3	*	*
Cicer milkvetch	1	0	*	*
Alfalfa - Rambler	1	0	*	*
Alfalfa - Drylander	1	0	*	*

* Did not assess because of slope failure.

[1] Western wheatgrass, slender wheatgrass, streambank wheatgrass hard sheep fescue and a Kentucky bluegrass were also planted. Plots for these five species were lost early because of slope failure.

Native Grass Species

Tables 3 and 4 summarize the results of the native grass plantings in 1975 and 1976 at nine different locations along the Eastern Slopes for three selected years. The results indicate that the overall survival rates were high, especially during the early years after planting, and decreased somewhat with time. It could be speculated that frost heaving played a role in seedling mortality; the container seedlings had been planted in somewhat coarse materials. Other problems observed during assessments which contributed to mortality are water and wind erosion, excessive grazing, and damage caused by recreational vehicles. Generally it can be said that all the native grasses grew well and had high survival rates. Deschampsia caespitosa and Poa alpina among the species seeded in 1975 (Table 3) and Agropyron latiglume, Festuca saximontana, Koeleria cristata, Poa alpina and Poa interior among those seeded in 1976 (Table 4) had the highest percentage of survival in 1982, the last year the plots were assessed. Flowering percentages of the surviving plants in these same species were among the best.

Tables 5 and 6 give the results of the native grass assessment in 1982 for five individual locations. In the southern third of the region (Adanac and Tent Mountain), Koeleria cristata, Poa interior, Poa alpina, Trisetum spicatum and Agropyron dasystachum had the highest percentage of survival. Agropyron latiglume grew very well and covered the entire plot in which it was planted. In the central part of the region (Bighorn Dam and Nordegg) several species had a high percentage of survival depending on the year of planting and location. Poa alpina,

Table 3

PERCENT SURVIVAL AND FLOWERING OF NATIVE GRASS CONTAINER SEEDLINGS PLANTED IN 1975 AT VARIOUS LOCATIONS IN THE EASTERN SLOPES

Species	Source	Survival (%)			Flowering (%)*	
		1976	1978	1982	1978	1982
Agropyron dasystachyum	Exshaw, 1 372 m	84	83	29[1]	7	19[1]
Deschampsia caespitosa	Whistler Mtn., 1 829 m	91	84	60[2]	81	67[2]
Festuca saximontana	Mt. Rae, 2 286 m	100	97	40[3]	97	25[3]
Poa alpina	Whistler Mtn., 2 347 m	82	69	33[4]	80	33[4]
Poa alpina	Mt. Rae, 2 286 m	97	97	88[5]	97	89[5]
Stipa columbiana	Pigeon Mtn., 1 675 m	64	45	36[6]	83	51[6]
Trisetum spicatum	Mt. Rae 2 286 m	94	84	40[6]	81	55[6]

[1] Adanac, Caw Creek Ridge and Lovett Tower.

[2] Bighorn Dam, Caw Creek Ridge and Lovett Tower.

[3] Bighorn Dam, and Caw Creek Ridge.

[4] Adanac, Bighorn Dam, Caw Creek Ridge and Lovett Tower.

[5] Lovett Tower and Nordegg.

[6] Adanac, Bighorn Dam, Caw Creek Ridge, Lovett Tower and Nordegg.

* Percent of plants surviving.

Table 4

PERCENT SURVIVAL AND FLOWERING OF NATIVE GRASS CONTAINER SEEDLINGS PLANTED IN 1976 AT VARIOUS LOCATIONS IN THE EASTERN SLOPES

Species	Source	Survival (%)			Flowering (%)**	
		1977	1978	1982	1978	1982
Agropyron dasystachyum	*	90	79	30[1]	9	48[1]
Agropyron latiglume	Peyto Lake, 2 194 m	90	85	***[2]	73	***[2]
Agropyron subsecundum	Kootenay Plains, 1 372 m	81	68	52[1]	46	62[1]
Agropyron trachycaulum	-	94	88	-	100	-
Bromus pumpellianus	*	85	75	46[3]	17	62[3]
Festuca saximontana	Caw Creek Ridge, 1 981 m	48	58	62[1]	95	68[1]
Koeleria cristata	*	81	79	72[1]	51	52[1]
Phleum alpinum	Peyto Lake, 2 194 m	92	80	23[1]	70	58[1]
Poa alpina	Whitehorn, 1 829 m	97	93	67[1]	80	38[1]
Poa interior	Whistler Mtn., 2 347 m	79	75	84[1]	94	52[1]
Stipa columbiana	-	66	66	25[4]	24	100[4]
Trisetum spicatum	Mountain Park, 2 042 m	76	65	40[1]	72	55[1]

* Some hybridization therefore source irrelevant.

** Percent of plants surviving.

*** Overgrown - entire plot covered by the species. Difficult to identify individual seedlings planted.

[1] Bighorn Dam, Caw Creek Ridge, Nordegg and Tent Mountain.

[2] Caw Creek Ridge and Tent Mountain.

[3] Caw Creek Ridge, Bighorn Dam and Nordegg.

[4] Bighorn Dam and Nordegg.

Table 5

PERCENT SURVIVAL AND FLOWERING IN THE EIGHTH (1982)
SEASON OF NATIVE GRASS CONTAINER SEEDLINGS PLANTED IN 1975

Species	Source	North				Central				South	
		Caw Ridge		Lovett		Bighorn		Nordegg		Adanac	
		S[1]	F[2]	S	F	S	F	S	F	S	F
Agropron dasystachyum	Exshaw, 1 372 m	38	33	25	25	*	*	*	*	25	0
Deschampsia caespitosa	Whistler Mtn., 1 829 m	94	100	56	100	31	0	-	-	-	-
Festuca saximontana	Mt. Rae, 2 286 m	75	50	-	-	6	0	-	-	-	-
Poa Alpina	Whistler Mtn., 1 829 m	100	100	0	0	19	0	-	-	12	0
Poa Alpina	Mt. Rae, 2 286 m	-	-	81	77	-	-	94	100	-	-
Stipa columbiana	Pigeon Mtn., 1 675 m	6	100	38	0	44	86	50	38	44	29
Trisetum spicatum	Mt. Rae, 2 286 m	56	100	0	0	12	0	75	33	56	33

[1] S = Survival (%) of seedlings planted.

[2] F = Flowering (%) of surviving seedlings.

* Plots overrun by rhizomes. Difficult to identify individual seedlings planted.

Table 6

PERCENT SURVIVAL AND FLOWERING IN THE SEVENTH (1982) SEASON OF NATIVE GRASS CONTAINER SEEDLINGS PLANTED IN 1976

Species	Source	North		Central				South	
		Caw Ridge		Nordegg		Bighorn		Tent Mtn.	
		S[1]	F[2]	S	F	S	F	S	F
Agropyron dasystachyum	*	0	0	25	100	38	0	56	44
Agropyron latiglume	Peyto Lake 2 194 m	**	**	-	-	-	-	**	**
Agropyron subsecundum	Kootenay Plains 1 372 m	50	75	56	33	56	56	44	86
Bromus pumpellianus	*	31	100	**	**	56	11	50	75
Festuca saximontana	Caw Creek Ridge 1 981 m	88	100	31	40	100	50	31	80
Koeleria cristata	*	88	57	38	33	62	30	100	88
Phleum alpinum	Peyto Lake 2 194 m	56	100	12	0	0	0	25	75
Poa alpina	Whitehorn 1 829 m	81	100	94	13	0	0	94	0
Poa interior	Whistler Mtn. 2 347 m	100	100	56	0	81	8	100	100
Stipa columbiana	--	-	-	12	100	38	100	-	-
Trisetum spicatum	Mountain Park 2 042 m	44	57	43	17	0	0	75	92

[1] S = Survial (%) of seedlings planted.

[2] F = Flowering (%) of surviving seedlings.

* Some hybridization therefore source irrelevant.

** Overgrown - entire plot covered by the species. Difficult to identify individual seedlings planted.

Poa interior and Agropyron subsecundum are among those species with the highest survival percentages. Agropyron latiglume grew very well and covered the entire plot in which it was planted. In the northern part (Caw Creek Ridge and Lovett Tower), several species had a high percentage of survival depending on the year, seed source and location. At Caw Creek Ridge Agropyron latiglume, Poa interior, Poa alpina, Deschampsia caespitosa, Festuca saximontana and Koeleria cristata survived very well. At Lovett Tower, Poa alpina of Mt. Rae origin and Deschampsia caespitosa had the best survival. Table 7 summarizes this information. Performances of the individual species are described by Mihajlovich and Hall, 1982.

In the containerized planting in 1977 at Cache Percotte, a low elevation site near Hinton, percent survival of the plants remained high at the end of the sixth growing season in all but two species (Table 8). Survival was excellent in Agropyron subsecundum, Agropyron trachycaulum, Festuca saximontana and Agropyron latiglume. Flowering was poor in only four of the species, and in one species (Agropyron spicatum) there was no evidence of flowering in the sixth year at assessment time. The species showing the best vigor were Festuca saximontana, Festuca idohoensis and Elymus canadensis.

Adaptability Trials

Cultivated Grasses and Legumes

Percentage of plant cover in the fifth season in the trials established at Tent Mountain in 1977 are given in Table 9. In several of

Table 7

NATIVE GRASS SPECIES WITH SOME POTENTIAL FOR RECLAMATION IN THE EASTERN SLOPES - BASED ON PERCENT SURVIVAL ON CONTAINERIZED SEEDLINGS (PLANTED IN 1975 AND 1976, AND ASSESSED IN 1982)

North (Caw Ridge, Lovett)	Central (Bighorn Dam, Nordegg)	South (Adanac, Tent Mtn.)
Agropyron latiglume (C)*	Agropyron Dasystachyum	Agropyron latiglume (T)
Poa interior (C)	Bromus pumpellianus (N)	Koeleria cristata (T)
Poa alpina	Poa interior	Poa interior (T)
Deschampsia caespitosa	Poa alpina (N)	Poa alpina (T)
Festuca saximontana (C)	Agropyron subsecundum	Trisetum spicatum
Koeleria cristata (C)	Koeleria cristata (B)	Agropyron dasystachum (T)
	Trisetum spicatum (N)	Stipa columbiana (A)

*A = Adanac; B = Bighorn Dam;
C = Caw Creek Ridge; N = Nordegg;
T = Tent Mountain.

No letter after a species indicates survival was high at each location under the column it appears.

Table 8
PERCENT SURVIVAL AND FLOWERING OF CONTAINERIZED NATIVE GRASS SEEDLINGS IN 1982 OF THE 1977 PLANTINGS AT CACHE PERCOTTE

Species	Survival (%)	Flowering[1]
Agropyron albicans	45.4	3
Agropyron dasystachyum	41.7	13
Agropyron latiglume	85.6	49
Agropyron smithii	33.5	9
Agropyron spicatum	61.9	0
Agropyron subsecundum	99.7	35
Agropyron trachycaulum	92.7	89
Agropyron sp.	30.3	52
Elymus canadensis	75.5	95
Festuca idahoensis	72.1	54
Festuca saximontana	96.9	90
Koeleria cristata	17.1	71
Phleum alpinum	60.0	69
Poa alpina	75.8	76
Poa cusickii	50.0	33
Poa interior	16.7	40
Trisetum spicatum	29.6	89

[1] Flowering (%) of surviving seedlings.

Table 9

PERCENT PLANT COVER IN THE FIFTH SEASON (1981)
AFTER SEEDING CULTIVATED GRASSES AND LEGUMES
AT TENT MOUNTAIN

Species	Raw Overburden	Topdressed Overburden
Creeping red fescue	45 b	43 a
Meadow fescue	24 defg	18 bcdef
Chewing fescue	70 a	32 ab
Artic fescue	41 bc	26 abcd
Tall fescue	12 ghij	18 bcdef
Pubescent wheatgrass	22 defgh	12 bcdef
Slender wheatgrass	18 efghi	12 bcdef
Crested wheatgrass	19 efgh	5 ef
Kentucky bluegrass	31 bcdef	27 abc
Canada bluegrass	38 bcd	24 abcde
Upland bluegrass	31 bcdef	10 cdef
Smooth bromegrass	34 bcde	10 cdef
Climax timothy	23 defgh	21 bcdef
Redtop	15 fghij	27 abcd
Highland bentgrass	12 ghij	13 bcdef
Russian wild rye	25 cdefg	2 f
Sainfoin	10 ghij	4 ef
Birdsfoot trefoil	1 j	6 def
Alfalfa	24 defg	29 abc
White clover	1 j	14 bcdef
Red clover	6 hij	14 bcdef
Alsike clover	2 ij	27 abcd
Sweet clover (white)	1 j	1 f
Sweet clover (yellow)	2 ij	2 f

Means in a column followed by the same letter are not significantly different at the 5% level (Duncan's Multiple Range Test).

the species, cover had declined from the levels measured before 1981. On the topdressed overburden, creeping red, chewing and arctic fescues, Kentucky and Canada bluegrasses, and red top still provided adequate cover. On the raw overburden, however, upland bluegrass and smooth bromegrass as well as those species listed for topdressed overburden produced adequate plant cover. Among the legumes, alfalfa was the best species on both raw overburden and topdressed overburden. With topdressing, however, white, red and alsike clover improved considerably over the plant cover on the raw overburden.

The results of the trials established at Cadomin in 1978 on topdressed spoil with nine cultivated grasses and legumes are summarized in Tables 10 and 11. Up to the end of the fourth season of growth (1981) when maintenance fertilization was carried out, all of the species, produced adequate plant cover. The same general observation was true for plant vigor and seedhead production. The sweet clover, a biennial, had reseeded by itself and therefore produced good plant stands in the fourth season. With no fertilization of the plots in 1982, percentage of plant cover and vigor decreased considerably in all species except alfalfa. Although there was an overall lowering of seedhead production in most species with the withdrawal of fertilizer in 1982, the changes were, in most cases, small.

Biomass production at the fourth growing season (plots fertilized annually) was generally high in all but the Kentucky bluegrasses. Legume production was high; including the alsike clover which had essentially disappeared in other trials at the site when it was seeded in a mixture with other cultivated grasses. The reduction in plant cover and

Table 10

PLANT COVER (PERCENT) AND DRY MATTER PRODUCTION (g/0.25 m^2) OF CULTIVATED GRASSES AND LEGUMES ON SPOIL TOPDRESSED WITH MINERAL SOIL AT CADOMIN

Species	Plant Cover		Dry Matter
	1981	1982[1]	1981
Kentucky bluegrass - nugget	68.8 a	35.0 e	19.3 a
Kentucky bluegrass - park	87.2 bcde	59.8 abc	44.3 ab
Bromegrass	98.0 e	64.5 bc	145.1 de
Creeping red fescue	93.5 de	73.1 ab	66.7 abc
Crested wheatgrass	81.8 abcd	39.6 e	110.8 cde
Timothy	91.3 cde	50.7 cde	83.7 bcd
Alsike clover	91.3 cde	4.0 f	124.8 cde
Alfalfa	99.2 e	83.0 a	171.0 e
Sweet clover	76.0 ab	4.3 f	138.3 de
Species mix (all above)	99.0 e	89.4 a	159.3 e

[1] No fertilizers applied in 1982.

Means followed by a common letter in a column in a given year are not significantly different at the 5% level (Duncan's Multiple Range Test).

Table 11

PLANT VIGOR* AND SEED HEAD PRODUCTION* OF CULTIVATED GRASSES AND LEGUMES ON SPOIL TOPDRESSED WITH MINERAL SOIL AT CADOMIN

Species	Plant Vigor		Seed Head	
	1981	1982[1]	1981	1982[1]
Kentucky bluegrass - nugget	5.5 ab	3.0 cde	4.5 a	4.2 abcde
Kentucky bluegrass - park	5.5 ab	2.0 e	5.0 ab	1.2 g
Bromegrass	6.5 bc	6.0 ab	6.3 cd	4.7 abc
Creeping red fescue	6.5 bc	5.0 abc	6.3 cd	3.5 abcdef
Crested wheatgrass	5.5 ab	3.2 cde	5.5 abc	4.5 abcd
Timothy	5.0 a	3.0 cde	6.0 abc	4.2 abcde
Alsike clover	7.0 c	2.7 de	7.0 d	2.5 cdefg
Alfalfa	7.0 c	6.2 ab	7.0 d	5.2 ab
Sweet clover	7.0 c	4.5 abcd	7.0 d	1.7 bcdef
Species mix (all above)	7.0 c	6.2 a	7.0 d	5.5 a

* Subjective rating based on a scale of 1 (poor) to 7 (excellent).

[1] No fertilizers applied in 1982.

Means in a column followed by a common letter are not significantly different at the 5% level. (Duncan's Multiple Range Test).

biomass production of the grass species which occurred in the fifth year (1982) are due to nitrogen deficiency and a low level of available phosphorus following discontinuation of maintenance fertilization in that year. Chlorosis and mortality in the grasses were common. Alfalfa and the species mix (containing alfalfa) maintained the best dry matter yields, vigor and seedhead production even after stoppage of annual maintenance fertilization, apparently due to the nitrogen-fixing ability of alfalfa. Alfalfa should be considered a good legume in seed mixtures for operational reclamation in similar environments.

Native Grasses

Plant cover levels in 1981 for several native grasses of different seed sources seeded at Tent Mountain in September, 1976, are given in Table 12. Plant cover was poor for most species, including the cultivated species used in the trials for comparison. Generally, plant cover for all of the species increased and peaked in 1979 (three seasons) and by 1981 had started to decline in all but two of the species; Festuca rubra and Poa interior. The best species after five seasons, in terms of cover production, were the three native Festucas (rubra, saximontana and idahoensis) and Koelaria cristata (Mount Stearn seed source). All four species gave higher plant cover than the cultivated species used for comparison. Stipa comata from the Kootenay Plains had died out by the third year and it did not regenerate in 1980 or 1981. Differences in cover between four of the five Agropyron subsecundums of different seed sources were small. The Region Mountain seed source produced the best cover among the five Agropyron seed sources. Koelaria cristata of

Table 12

PERCENT PLANT COVER IN NATIVE GRASS SPECIES PLANTED AT TENT MOUNTAIN IN SEPTEMBER, 1976

Species	Source	1977	1979	1981
Agropyron subsecundum	Athabasca Ranch, 1 018 m	16	31	14
Agropyron subsecundum	Bragg Creek, 1 829 m	9	16	13
Agropyron subsecundum	Grotto Mtn., 1 433 m	12	34	15
Agropyron subsecundum	Kootenay Plains, 1 372 m	14	35	12
Agropyron subsecundum	Pigeon Mtn., 1 524 m	13	31	21
Agropyron trachycaulum	Gibraltar Mtn., 1 829 m	7	26	20
Agropyron trachycaulum	Waterton, 1 372 m	8	22	17
Agrostis scabra	Gibraltar Mtn., 1 829 m	11	32	8
Festuca idahoensis	Windsor Ridge, 1 737 m	14	38	40
Festuca rubra	Rampart Creek, 1 448 m	22	58	75
Festuca saximontana	Mt. Rae, 2 286 m	18	44	37
Koeleria cristata	Grotto Mt., 1 433 m	13	29	22
Koeleria cristata	Mt. Stearn, 1 646 m	19	46	33
Phleum alpinum	Cut creek, 1 585 m	6	14	13
Poa interior	Whistler Mtn., 2 347 m	8	11	19
Stipa comata	Kootenay Plains, 1 372 m	2	0	0
Trisetum spicatum	Whitehorn Mtn., 2 012 m	22	28	20
Agropyron trachycaulum 'Revenue'[1]	- - -	18	43	24
Calamagrostis purpurascens var. commutata*[1]	Nihahi Ridge, 1 829 m	8	10	17

* Unknown cultivar.

[1] Cultivated species

Mt. Stearn seed source produced 50% more cover than the Grotto Mountain seed source. Continued high plant cover production with no maintenance fertilization (plots fertilized at time of seeding) for the Festuca rubra of Rampart Creek seed source, up to five seasons after seeding, indicates the good potential of this species collected at that location for reclamation in the region.

The native grass species adaptability trial started at Cadomin in 1978 showed considerable differences in percentage of plant cover between species after four seasons of growth (Table 13). Between seeding and the fourth season, the plots were fertilized annually in June. During this period, cover increased progressively in all but one species. In every species, cover in 1981 was the highest it had ever been. The three native Agropyrons (dasystachum, subsecundum and trachycaulum), the Deschampsia caespitosa and the native Festuca (rubra and saximontana) along with the two cultivated species (Agropyron trachycaulum, "Revenue" and Festuca rubra, "Boreal") produced the highest plant cover. All of the plots grew well and rated good in plant vigor up to and including 1981 since they were fertilized annually. None of the plots were fertilized in 1982 or 1983. Observations in 1982 and 1983 indicated that both productivity and plant vigor had started to decline; the change being particularly apparent in 1983.

CONCLUSIONS

The demonstration plantings of native and cultivated grass species and legume species across the foothills on land disturbances, and the

Table 13

PERCENT PLANT COVER AND PLANT VIGOR* OF NATIVE GRASS SPECIES ON OVERBURDEN TOPDRESSED WITH MINERAL SOIL AT CADOMIN (TRIAL ESTABLISHED IN 1978)

Species	Plant Cover		Plant Vigor
	1979	1981	1981
Agropyron dasystachyum	26.1 e	57 ef	4.5 abc
Agropyron subsecundum	20.9 de	42 abcde	3.8 a
Agropyron trachycaulum	20.5 de	48 bcdef	4.5 abc
Calamagrostis purpurascens	4.1 ab	31 ab	5.5 c
Deschampsia caespitosa	10.0 bc	44 abcdef	5.8 c
Festuca idahoensis	2.6 ab	31 a	5.5 c
Festuca saximontana	4.1 ab	41 abcde	4.8 abc
Festuca rubra	14.5 cd	46 bcdef	4.8 abc
Koelaria cristata	4.1 ab	38 abcde	5.3 bc
Phleum alpinum	8.1 abc	35 abc	4.0 ab
Poa interior	3.0 ab	30 a	4.3 abc
Stipa columbiana	0.6 a	30 a	4.5 abc
Trisetum spicatum	7.2 abc	36 abc	4.0 ab
Agropyron trachycaulum 'Revenue'[1]	15.0 cd	51 cdef	4.8 abc
Festuca rubra 'Boreal'[1]	21.2 de	60 f	5.8 c

* Subjective rating based on a scale of 1 (poor) to 7 (excellent).

[1] Cultivated species.

Means in a column followed by the same letter are not significantly different at the 5% level (Duncan's Multiple Range Test).

adaptability trials on abandoned surface mine disturbances in the same region, have provided the following information:

1. In terms of plant cover and biomass production, the cultivated grasses have performed well for the duration of the studies (up to seven seasons). In the southern part of the region (Tent Mountain), the fescues, bluegrasses, crested wheatgrass and red top grew well. In the northern part (Cadomin) all six cultivated grasses grew well.

2. Alfalfa, among the relatively-few legumes planted, performed best and should be seriously considered in the seed mixtures used in the sub-alpine region. It was observed to have done very well when grown alone, and to have improved plant cover in plots where it was a component of the seed mix.

3. The native grasses persisted and provided adequate plant cover in some instances, but they were generally slower than the cultivated grasses in developing adequate plant cover. There were distinct differences among the species. Generally, the Agropyrons, the Festucas and the Poas appear to persist well across the region in most of the plantings. There were, however, definite differences among species on disturbances at given locations. The choice of a species for ground cover establishment should be dictated primarily by the location and the severity of the site.

4. Our operational experience in the high alpine region shows that cultivated grasses grow well and have persisted longer than eight years without dying out. The information summarized in

this paper suggests that most of the cultivated grasses will grow and perform fairly well on disturbances in the region. The choice of a species for particular reclamation conditions should be dictated primarily by the regional conditions and the microsite conditions.

REFERENCES

King, P. 1980. Tent Mountain Demonstration Plantings - 1979. Alberta Department of Energy and Natural Resources, Alberta Forest Service, Edmonton.

Mihajlovich, M.M. and Hall, L. 1982. Reclamation Experiments in the Eastern Slopes of Alberta. Final Report prepared for the Reclamation Research Technical Advisory Committee. RRTAC Project 82-12-Tom. Alberta Department of Energy and Natural Resources, Alberta Forest Service, Edmonton.

Mihajlovich, M.M. and Russell, W.B. 1980. Tent Mountain Reclamation Demonstration Plantings, 1977 and 1978. Alberta Department of Energy and Natural Resources, Alberta Forest Service, Edmonton.

Russell, W.B. and Takyi, S.K. 1979. The Cadomin Reclamation Research Project. First year results (1978). Alberta Department of Energy and Natural Resources, Alberta Forest Service, Edmonton.

Selner, J. 1973. Surface Mine Reclamation Research in Alberta. Progress Report. Alberta Department of Lands and Forests, Alberta Forest Service, Edmonton.

Selner, J. and King, P. 1977. Native Grass Study. Species Adaptability Trials. ENR Report No. 18. Alberta Department of Energy and Natural Resources, Alberta Forest Service, Edmonton.

Selner, J., King, P. and Hildebrandt, D. 1977. Progress Report for Tent Mountain Coal-mined Land. Reclamation Trials (1975-76). Alberta Department of Energy and Natural Resources, Alberta Forest Service, Edmonton.

Takyi, S.K. 1984. Role of Topsoil, Fertilizers and Companion Crops in Revegetation of Two Severe Sites in the Alberta Foothills and Mountains. ENR Report No. T/67. Alberta Department of Energy and Natural Resources, Alberta Forest Service, Edmonton.

____. 1984. Plant Cover Establishment Methods on a Severe Rocky Mountain Foothills Site. ENR Report No. T/66. Alberta Department of Energy and Natural Resources, Alberta Forest Service, Edmonton.

Takyi, S.K. and Russell, W.B. 1980. The Cadomin Reclamation Research Project. Second Year Results (1979). Alberta Department of Energy and Natural Resources, Alberta Forest Service, Edmonton.

Tomm, H. 1982. Progress Report on the Tent Mountain Grass and Legume Reclamation Trials. Alberta Department of Energy and Natural Resources, Alberta Forest Service, Edmonton.

BOW VALLEY REVEGETATION TRIALS

by

D.G. Walker and G. Harrison*

ABSTRACT

A revegetation study was conducted on an abandoned roadbed in the Bow River valley, Banff National Park. Test plots were monitored over four years for plant establishment, ground cover, plant vigour, and invasion of other species. Boreal creeping red fescue and Banff Kentucky bluegrass produced the highest cover but had the lowest cover of invader species. Reubens Canada bluegrass, Revenue slender wheatgrass, and Sherman big bluegrass were rated as good or better than Boreal in plant vigour. Evergreen timothy and Sodar Streambank wheatgrass were rated acceptable; native alpine timothy was unacceptable. Heavy fertilization at the time of seeding increased ground cover over the study period but did not affect initial seedling establishment. Heavy seeding rates increased ground cover but reduced plant vigour (height).

INTRODUCTION

Parks Canada is charged with the responsibility of administering the rehabilitation of Park lands which have been disturbed by development or recreational activities. The mandate also requires that the resources of the Parks be maintained in a natural state to serve as a museum of nature for the enjoyment and education of future generations. Short-term rehabilitation objectives may sometimes include erosion control or forage production for wildlife but restoration of an indigenous vegetation community is always the final target. Rehabilitation techniques must be determined and applied to encourage the invasion of native species and the eventual development of a native plant community.

---

*Of Walker & Associates and Parks Canada respectively

This study was undertaken to identify techniques and plant species for rehabilitation in the mountain Parks. Specific objectives were:

(1) To compare the suitability of eight grass varieties with Boreal creeping red fescue, a proven variety commonly used for reclamation in the foothills and mountain regions of Alberta; and

(2) To examine the performance of five native and three exotic species of grass when established at three rates of seed and fertilizer.

DESCRIPTION OF THE STUDY SITE

The study site is located on an abandoned section of the Bow Valley Parkway road in Banff National Park. The asphalt surface had been previously removed exposing the coarse aggregate originally laid for the road foundation. The roadbed separates a predominantly lodgepole pine forest from a willow wetland.

The forest is dominated by lodgepole pine (*Pinus contorta*), with some aspen (*Populus tremuloides*) and white spruce (*Picea glauca*) also present. Buffaloberry (*Shepherdia canadensis*), bearberry (*Arctostaphylos uva-ursi*) provides the greatest understory cover, however, juniper (*Juniperus communis*), rose (*Rosa acicularis*), spike trisetum (*Trisetum spicatum*), pumpelly bromegrass (*Bromus pumpellianus*), hairy wild ryegrass (*Elymus innovatus*), bearded wheatgrass (*Agropyron subsecundum*), and bluegrasses (*Poa spp.*) are also common. Aspen is the dominant tree of the shrubland to the south, while willow species provide a high understory cover.

The study site is located on a well-drained, gentle slope of low erosion potential. Elevation of the site is 1390 m A.S.L.; treeline is 2200 m at this latitude. The abandoned roadbed is a narrow disturbance with undisturbed native vegetation on either side thereby affording a plentiful source of invading native species throughout the monitoring period. The site is shaded from direct sunlight for most of the day and the sheltered location provides considerable protection from dessication by both winter and summer winds. Frequent summer frosts and low growing degree-day accumulations are serious limitations to plant growth.

METHODS

PLOT ESTABLISHMENT

Test plots were established on September 19, 1979. A section of the abandoned roadbed was scarified with a heavy set of pipe harrows drawn with a light truck. For both the Variety Trial and the Seed/Fertilizer Rate Trial, a single species was broadcast seeded onto a 1 m^2 plot and the seed was covered by light raking.

The Variety Trial consisted of nine species (Table 1) seeded at a rate of 60 kg/ha in six replications using a completely randomized layout. The plots were fertilized at the time of seeding with 126 kg/ha of nitrogen in the form of ammonium nitrate and 96 kg/ha of phosphorus as ammonium phosphate. The Seed/Fertilizer Rate Trial consisted of eight species (Table 2) seeded at three rates: 20, 60, and 120 kg/ha. Ammonium nitrate and ammonium phosphate fertilizers were applied at the time of seeding at three rates: 126 kg-N/ha plus 96 kg-P/ha (high rate), 30 kg-N/ha plus 24 kg-P/ha (low rate), and no fertilizer (check). The three fertilizer rates were treated as three experiments each with four completely randomized replications of each seed-rate/species combination. Species data was pooled to assess treatment effect. Seed and fertilizer were weighed with a laboratory balance accurate to 0.1 g.

Table 1. Species used in the Variety Trials.

Common Name	Variety	Scientific Name	Source
Kentucky bluegrass	Nugget	*Poa pratensis*	naturalized, USA
Kentucky bluegrass	Banff	*Poa pratensis*	exotic, Alberta
Canada bluegrass	Reubens	*Poa compressa*	naturalized, USA
Big bluegrass	Sherman	*Poa ampla*	native, USA
Dwarf timothy	Evergreen	*Phleum bertolonii*	exotic, Sweden
Alpine timothy	unlicenced	*Phleum alpinum*	native, local
Creeping red fescue	Boreal	*Festuca rubra*	exotic, Alberta
Slender wheatgrass	Revenue	*Agropyron trachycaulum*	native, Sask.
Streambank ""	Sodar	*Agropyron riparium*	native, USA

Table 2. Species used in the Seed/Fertilizer Rate Experiment

Common Name	Variety	Scientific Name	Source
Bearded wheatgrass	unlicenced	*Agropyron subsecundum*	native, local
Slender wheatgrass	unlicenced	*Agropyron trachycaulum*	native, local
Streambank ""	unlicenced	*Agropyron riparium*	native, local
June grass	unlicenced	*Koeleria cristata*	native, local
Spike trisetum	unlicenced	*Trisetum spicatum*	native, local
Hard fescue	Durar	*Festuca ovina duriuscula*	naturalized, USA
Canada bluegrass	Reubens	*Poa compressa*	naturalized, USA
Crested wheatgrass	Parkway	*Agropyron cristatum*	exotic, Sask.

PLOT ASSESSMENT

Seedling establishment was measured one year after planting by counting the total number of seedlings in each plot. In the first, second and third years of assessment, height of seeded species was measured and ground cover of seeded and invading species was determined. A 1 m square quadrat with a 10 cm grid was used to visually estimate ground cover. Height refers to the average height of the tallest leafy stems of seeded species in each plot. The variety trial was assessed in the fourth year for plant vigour. Vigour refers to a qualitative assessment of the plots with a rating of 5 being the best. For a plot to rate 5, most of the plants had to have produced seeds, were multiplying outside the perimeter of the plot, and were large and robust. Statistical significance of the data has not been reported.

RESULTS

VARIETY TRIAL

Results of seedling establishment (Figure 1) have been expressed in terms of the number of seedlings alive after one year per gram of seed sown. The two Kentucky bluegrass varieties and the Canada bluegrass variety produced the greatest number of seedlings/gram but all varieties including the one locally collected native species, alpine timothy, established a high density of seedlings at the 60 kg/ha seeding rate. Observed seedlings per 1 m^2 square plot ranged from a low of 460 (Sodar streambank wheatgrass) to a high of over 1300 (Reubens Canada bluegrass). Considering the poor soil quality of the site, it is doubtful that these plant densities could be sustained without maintenance and therefore a considerable amount of die-off caused by overcrowding is suspected. In addition, a high density of seeded species may not be conducive to the invasion of native species into the stand. The data on seedlings/g from this experiment, if combined with experimental data from other sites, could be useful for the design of seed mixtures and variety-specific seeding rates which might result in stands of vegetation with a predetermined species composition and plant density.

Average ground cover three years after seeding is shown in Figure 2. Cover peaked in the second year for alpine timothy, Evergreen timothy, Reubens Canada bluegrass and Sodar Streambank wheatgrass while the other species continued to increase in the third year. Because the species differ in genetically controlled characteristics such as growth habit, growth rate, biomass, and competitive ability, these results should be interpreted in conjunction with total plant cover (Figure 3) and plant vigour assessment (Figure 4). Total cover, seeded species plus invaded species, ranged from 53% (Sodar) to 77% (Banff) with the rest of the species clustered between 56% and 69%. Sodar, alpine timothy, and Nugget had the lowest plant vigour and were surrounded by invader species. Revenue, Reubens, and Sherman had good plant vigour but the plots also recorded an above average amount of ground cover attributable to invader species. Boreal creeping red fescue has been shown in this trial and in many others conducted in the foothills and mountains of Alberta to be a well adapted and moderately aggressive species. Banff and Evergreen appeared to be in a state of decline in terms of plant vigour and are not expected to last over the longer term as the effect of fertilization declines and the

competition from invader species continues. The poor performance of alpine timothy may be characteristic of that particular selection only and should not be interpreted as a condemnation of the whole species.

SEED/FERTILIZER RATE TRIAL

Fertilization in conjunction with seeding had a positive effect on ground cover after one year (Figure 5) but had a neutral effect on seedling establishment. While the data concur with the well documented response of plants to fertilizer, it appears to contradict the commonly held belief that fertilizer is required to establish vegetation. Seeding rate had an effect on both establishment and ground cover (Figure 6). The average percent ground cover of all species after one year was 4% at a seeding rate of 20 kg/ha and 8% at 120 kg/ha. For the same seeding rates, the average percent seedling establishment dropped from 18% to less than 10%, most probably due to intraspecific competition.

The moderate rate of fertilization had a shorter term effect on ground cover than the heavy rate (Figure 7). In the third year, the average of the check plots was almost the same as the moderate rate, 24% vs 25%, but the average in plots amended with the heavy rate was over 33%. It should be noted that both the time of application and fertilizer formula were not ideal for efficient utilization by the plants. Ammonium nitrate is water soluble and subject to leaching and run-off losses. The early fall application left a considerable length of time for this to occur before uptake by seedlings the following summer. Fertilization several weeks after seedling emergence would have been a more efficient time for plant utilization. A direct correlation between ground cover and fertilization rate is not valid for this data because it is probable that only a small portion of the nitrogen from the moderate and heavy application rates actually reached the plant tissues.

Differences in ground cover attributable to seeding rate were apparent over the study period (Figure 8) but were not large. In the third year the 20, 60, and 120 kg/ha seeding rates had produced ground cover values of 24%, 29%, and 30% respectively. The need for an immediate and dense ground cover are often cited as the reason for using heavy seeding rates, however, the results of this experiment do not support this premise.

Height is one measure of plant vigour. Measurements made over three years suggest that fertilization had a positive effect throughout (Figure 9). In contrast, seeding rate had a negative effect on the average height of plants (Figure 10) in that it declined with an increase in seeding rate. This is interpreted as proof that the moderate (60 kg/ha) and heavy (120 kg/ha) seeding rates caused some reduction in plant vigour because of intraspecific competition. While this experiment examined species grown as a monoculture, it is speculated that interspecific competition resulting from the heavy seeding of a mixture of species could manifest itself not only by reduced plant vigour but also by the elimination of less aggressive species. This could be an explanation for the monocultures often observed on reclaimed sites that had originally been heavily seeded with a mixture. The subject certainly warrants further investigation.

CONCLUSIONS

All species examined in the variety trial were capable of establishing a more than sufficient stand density when seeded at 60 kg/ha. Boreal creeping red fescue and Banff Kentucky bluegrass achieved the highest ground cover after three years but also had the smallest proportion of invader species. The best plant vigour after four years was demonstrated by Boreal, Reubens Canada bluegrass, Sherman big bluegrass, and Revenue slender wheatgrass. Evergreen timothy, Nugget Kentucky bluegrass and Sodar streambank wheatgrass appeared adequate in terms of short-term performance. Alpine timothy, a locally collected, native selection was poor in terms of performance.

Fertilization at the time of seeding had a positive effect on ground cover that lasted at least three years. Fertilization did not effect the amount of initial plant establishment. High seeding rates increased ground cover marginally but reduced plant vigour as measured by height.

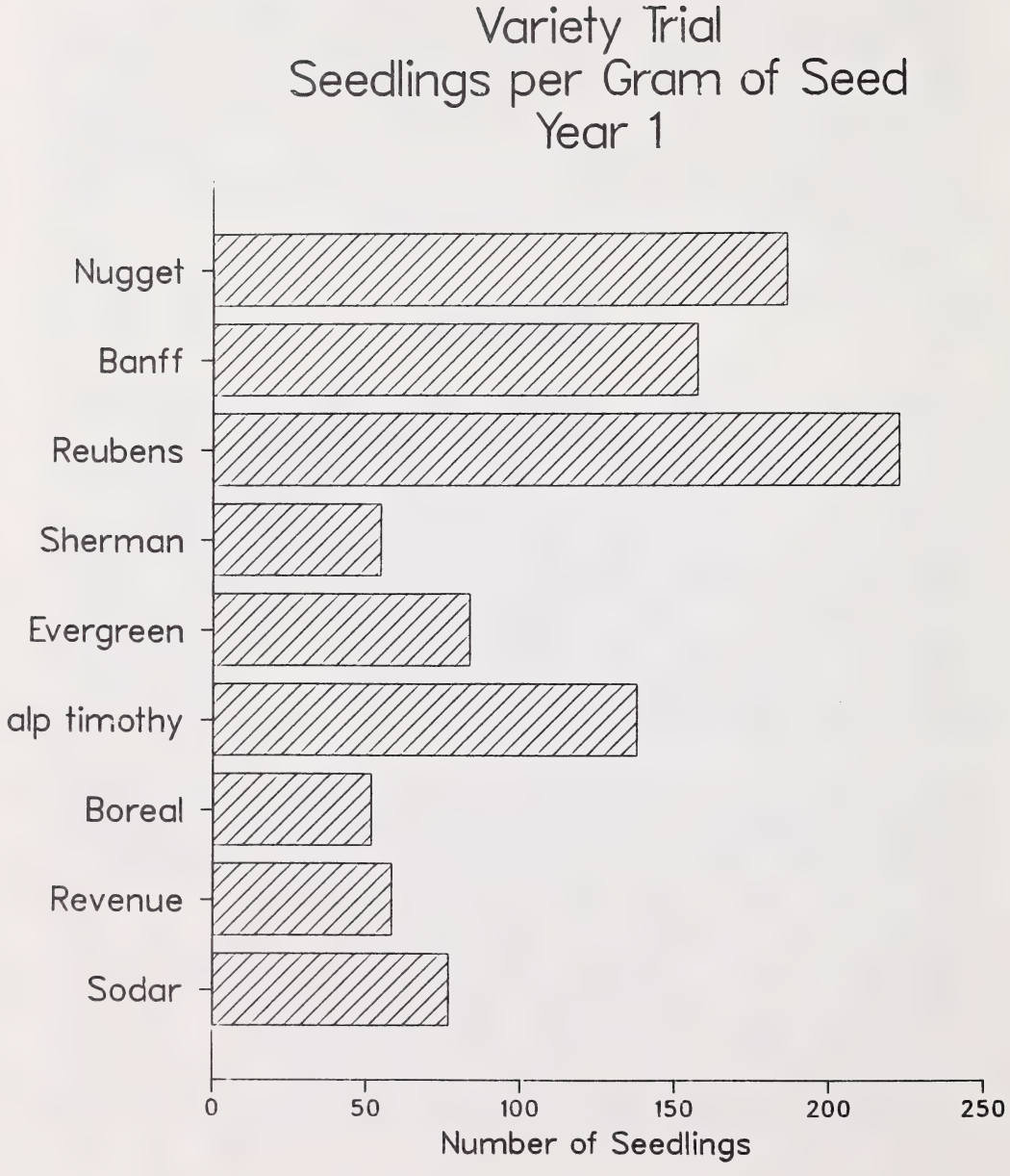

Variety Trial
Seedlings per Gram of Seed
Year 1
Nugget
Banff
Reubens
Sherman
Evergreen
alp timothy
Boreal
Revenue
Sodar
0
50
100
150
200
250
Number of Seedlings

Figure 1

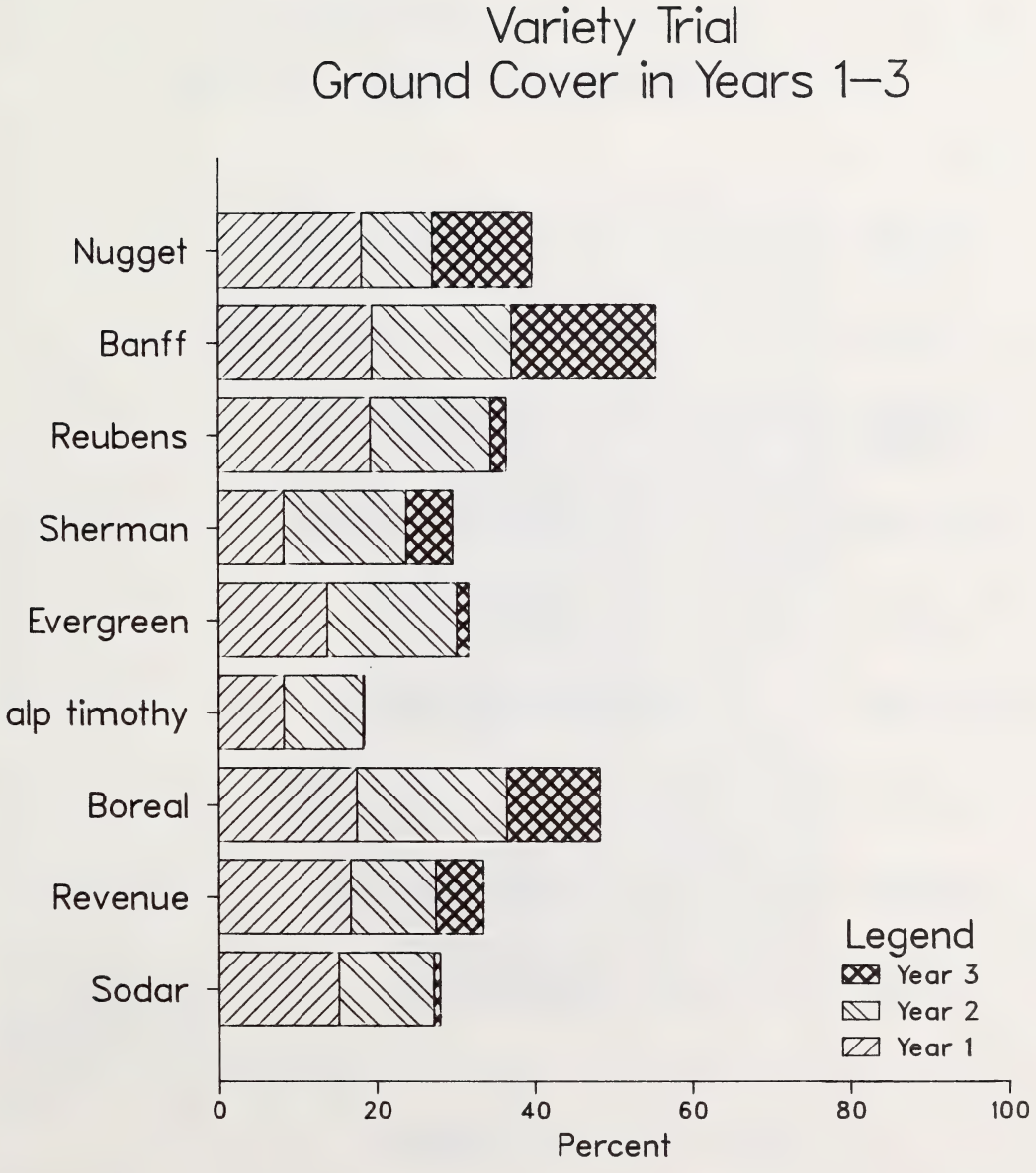

Variety Trial
Ground Cover in Years 1–3
Nugget
Banff
Reubens
Sherman
Evergreen
alp timothy
Boreal
Revenue
Sodar
Legend
Year 3
Year 2
Year 1
0
20
40
60
80
100
Percent

Figure 2

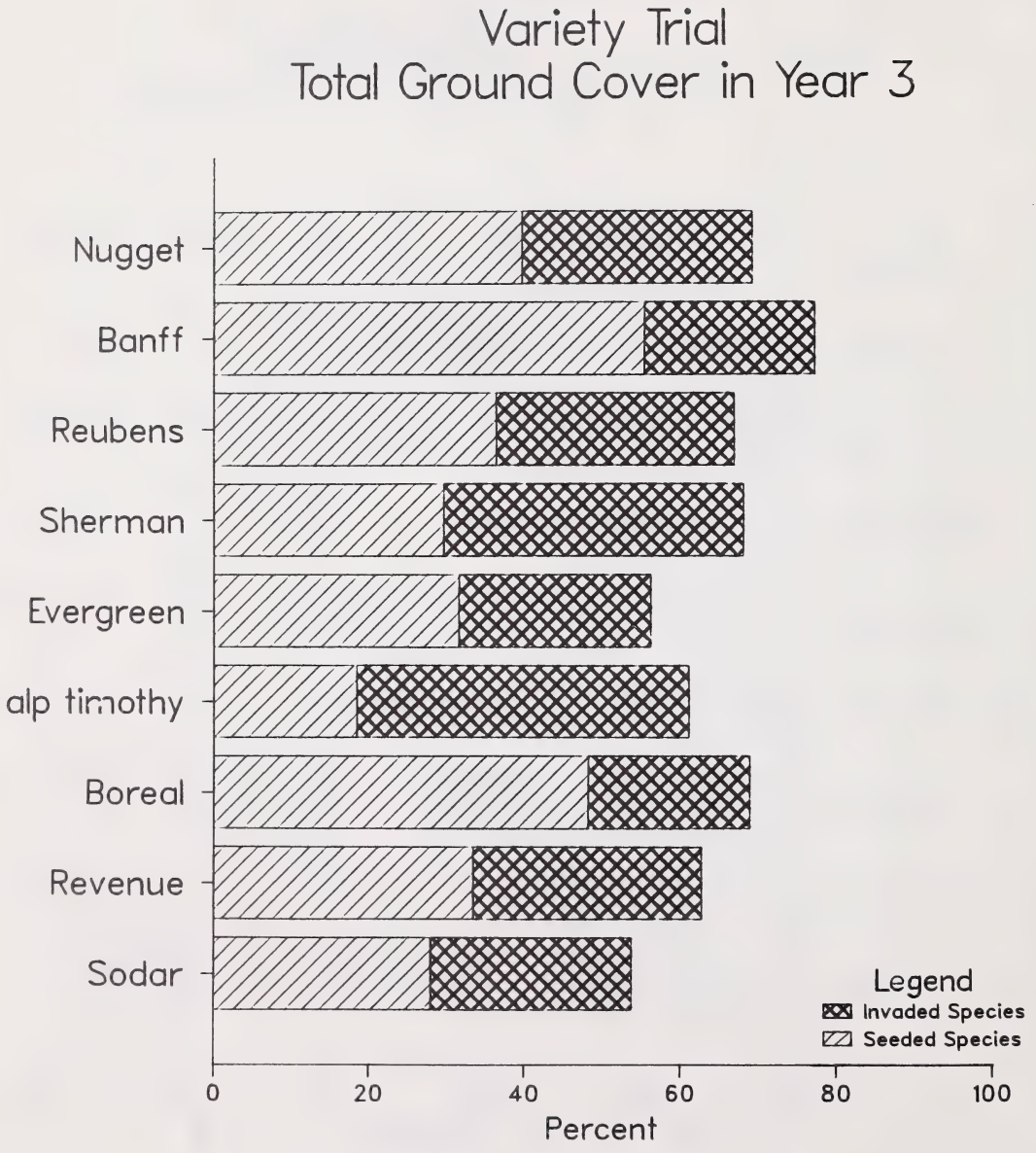

Variety Trial
Total Ground Cover in Year 3
Nugget
Banff
Reubens
Sherman
Evergreen
alp timothy
Boreal
Revenue
Sodar
Legend
Invaded Species
Seeded Species
0
20
40
60
80
100
Percent

Figure 3

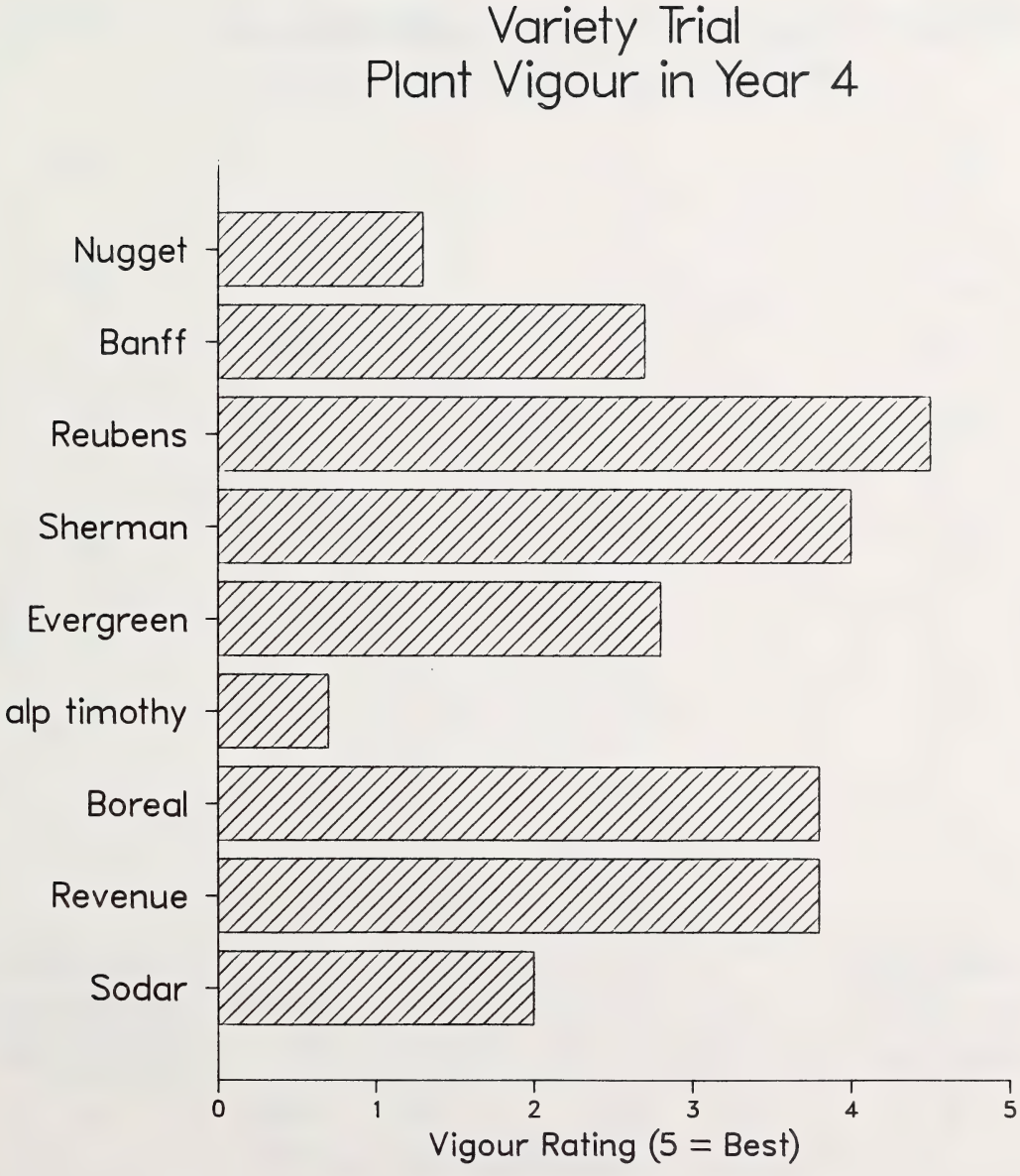

Variety Trial
Plant Vigour in Year 4
Nugget
Banff
Reubens
Sherman
Evergreen
alp timothy
Boreal
Revenue
Sodar
0
1
2
3
4
5
Vigour Rating (5 = Best)

Figure 4

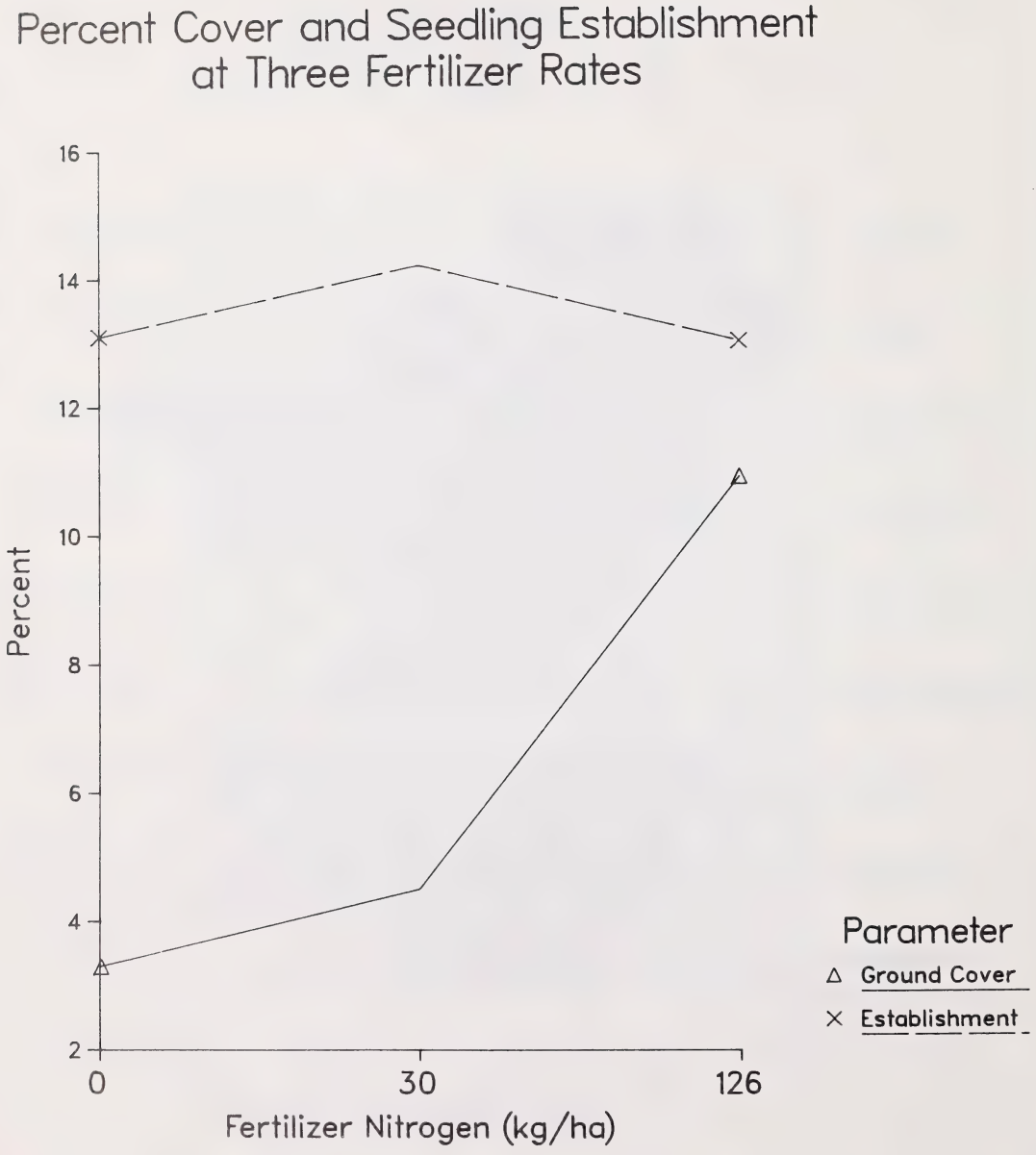

Percent Cover and Seedling Establishment
at Three Fertilizer Rates
16
14
12
10
8
6
4
2
Percent
0
30
126
Fertilizer Nitrogen (kg/ha)
Parameter
Ground Cover
Establishment

Figure 5

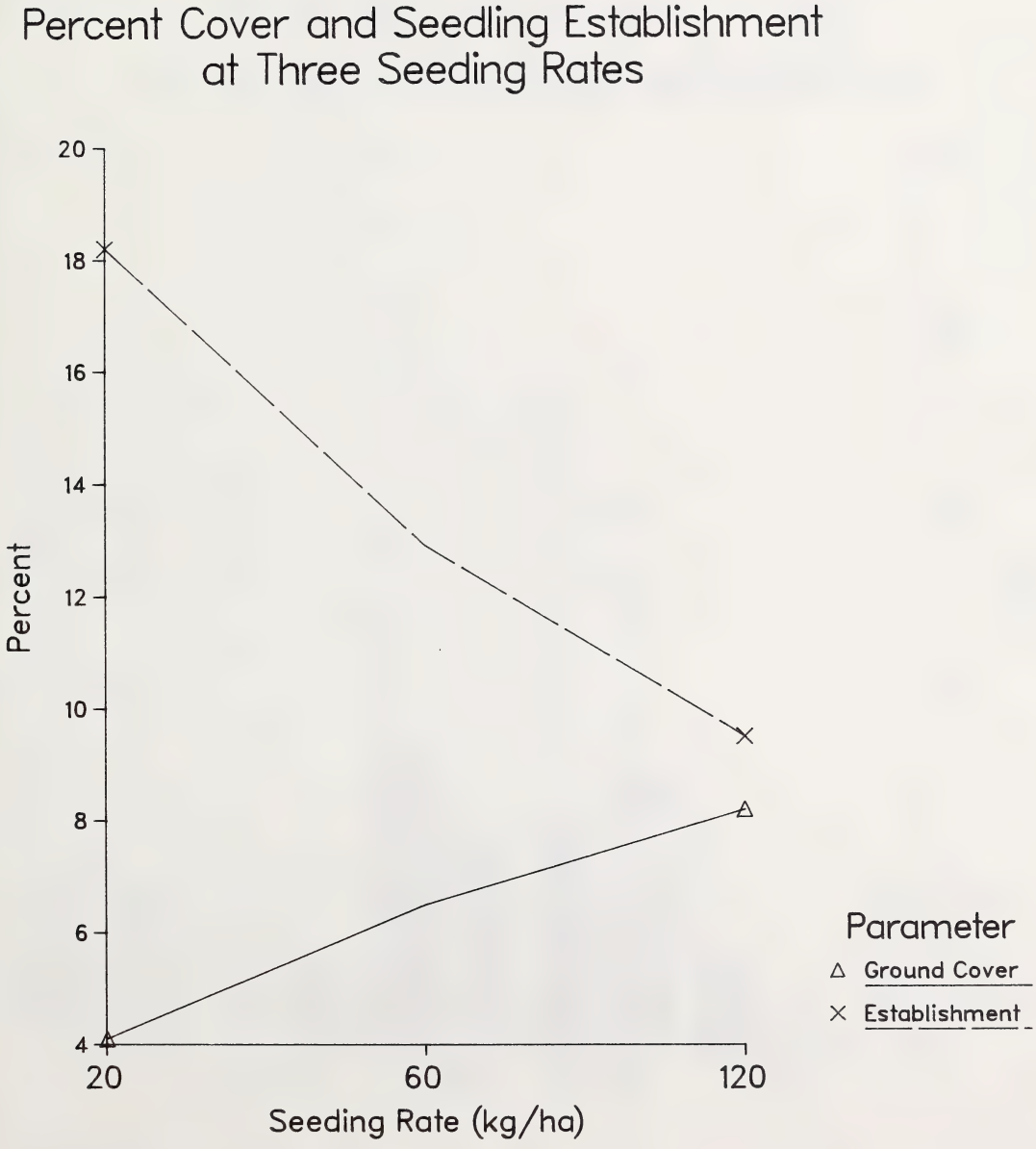

Percent Cover and Seedling Establishment
at Three Seeding Rates
Percent
20
18
16
14
12
10
8
6
4
20
60
120
Seeding Rate (kg/ha)
Parameter
Ground Cover
Establishment

Figure 6

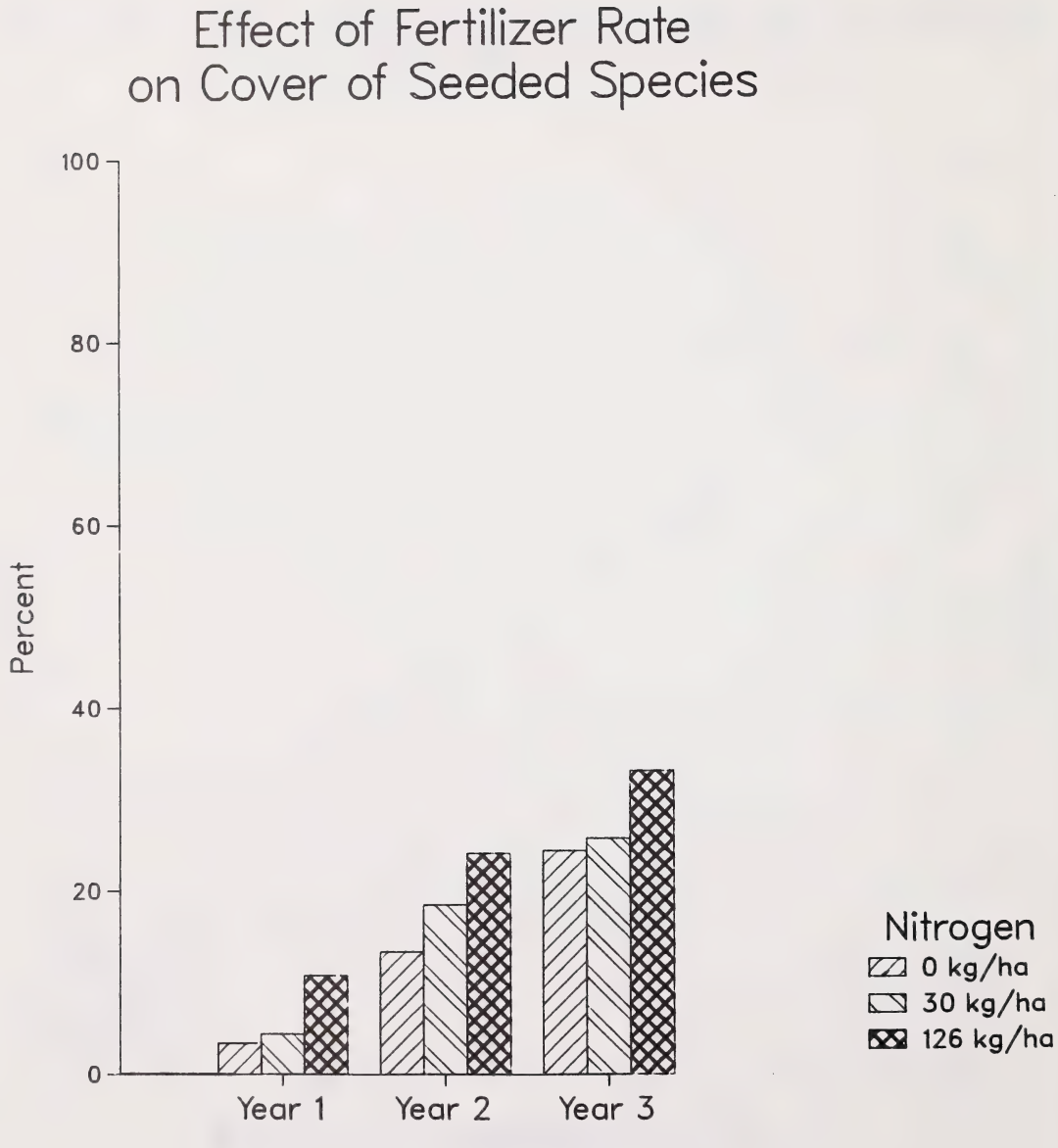

Effect of Fertilizer Rate
on Cover of Seeded Species
100
80
60
40
20
0
Percent
Year 1
Year 2
Year 3
Nitrogen
0 kg/ha
30 kg/ha
126 kg/ha

Figure 7

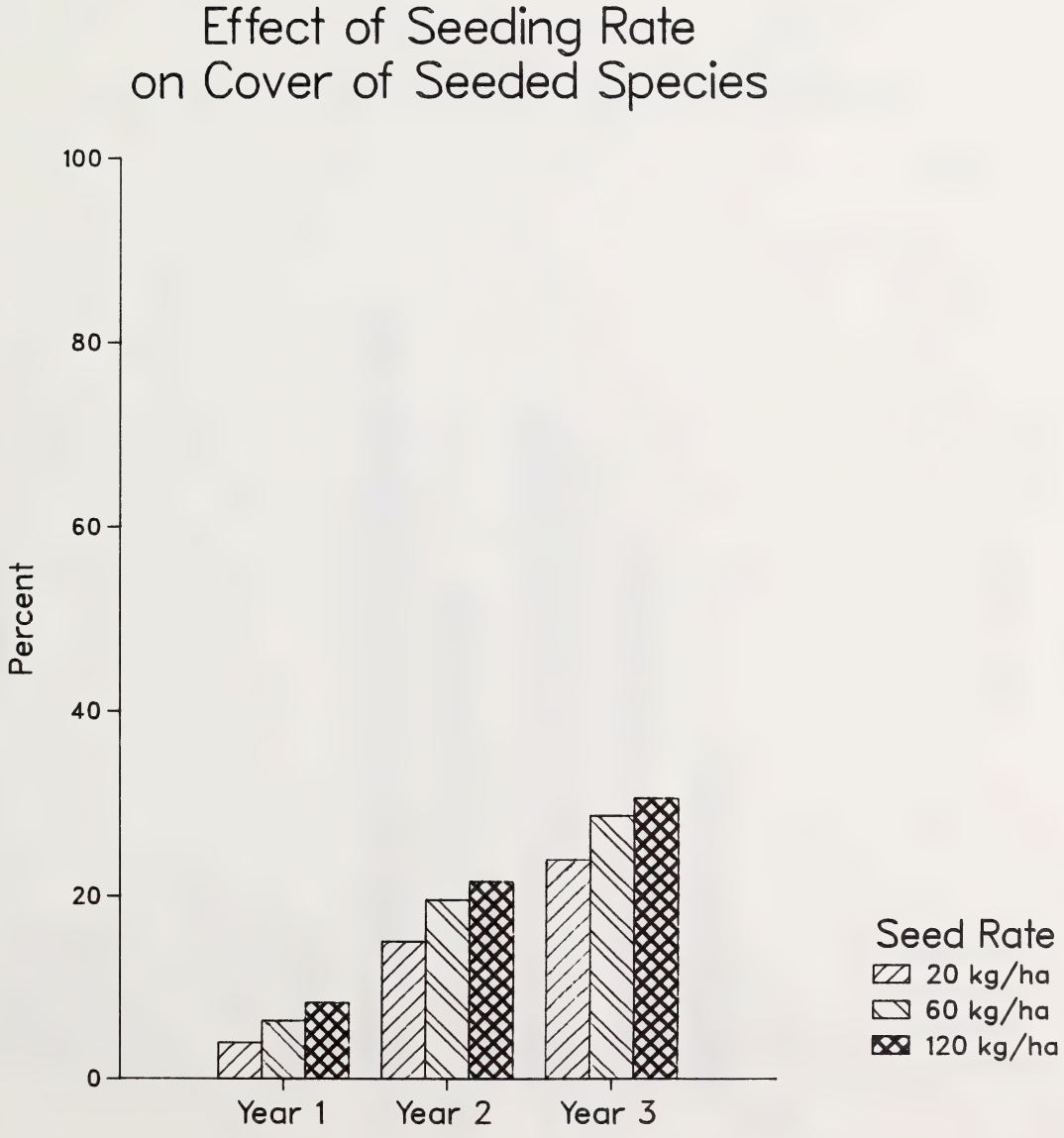

Effect of Seeding Rate
on Cover of Seeded Species
100
80
60
40
20
0
Percent
Year 1
Year 2
Year 3
Seed Rate
20 kg/ha
60 kg/ha
120 kg/ha

Figure 8

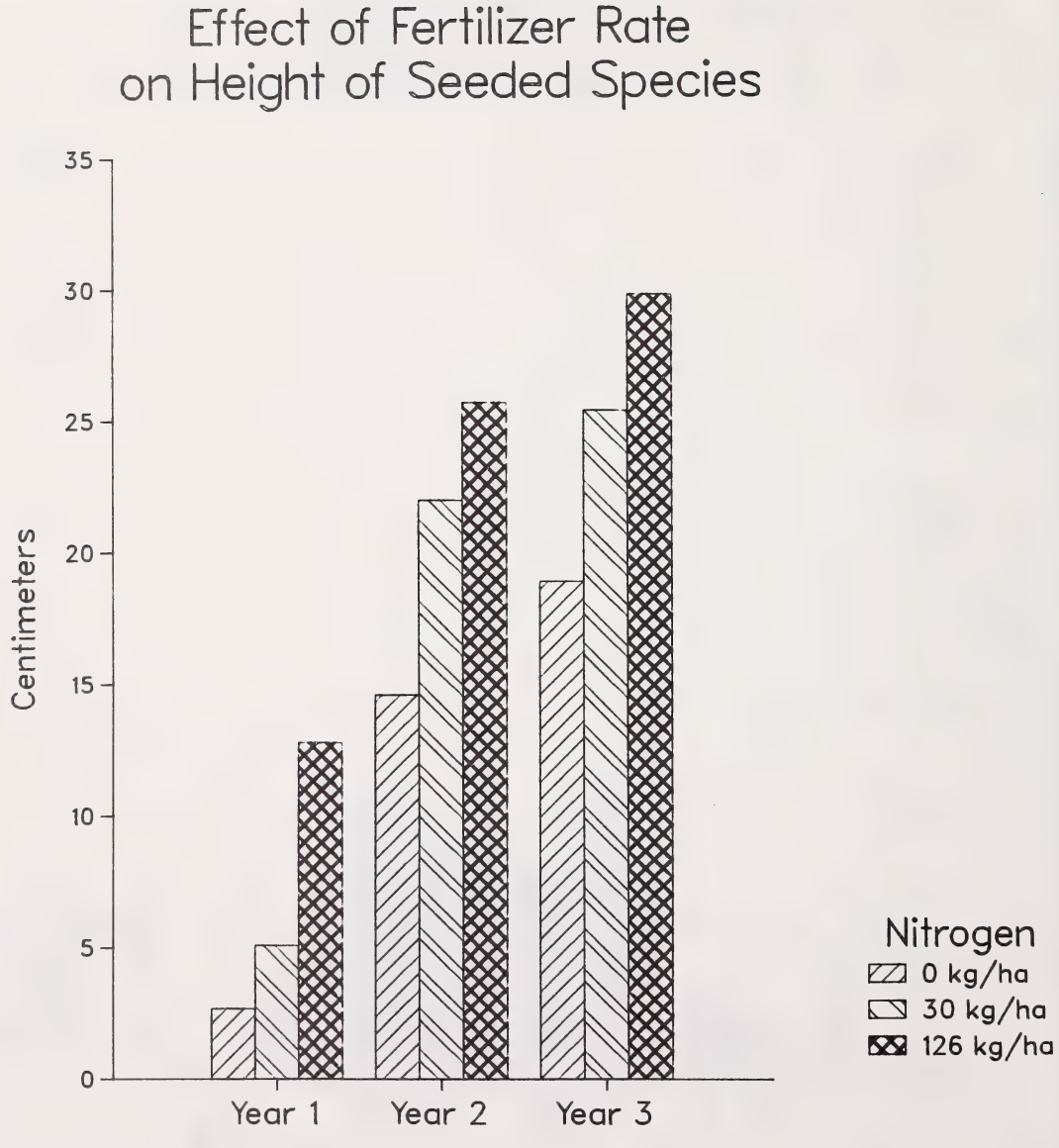

Effect of Fertilizer Rate
on Height of Seeded Species
Centimeters
35
30
25
20
15
10
5
0
Year 1
Year 2
Year 3
Nitrogen
0 kg/ha
30 kg/ha
126 kg/ha

Figure 9

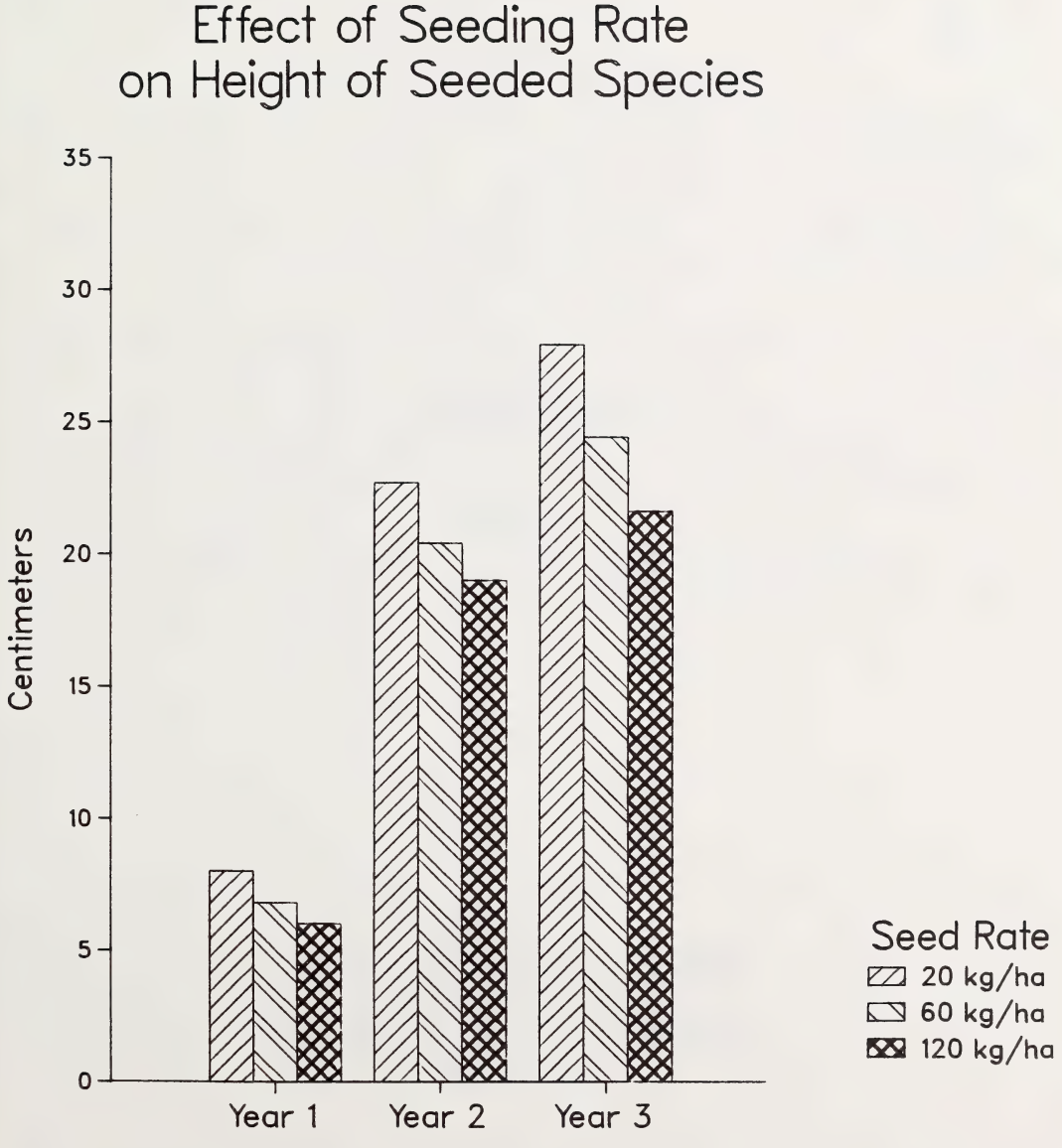

Effect of Seeding Rate
on Height of Seeded Species
Centimeters
35
30
25
20
15
10
5
0
Year 1
Year 2
Year 3
Seed Rate
20 kg/ha
60 kg/ha
120 kg/ha

Figure 10

AR/83/79-23-WEI

EFFECTS OF TOPSOILING, MAINTENANCE FERTILIZATION AND SPECIES SELECTION ON LONG-TERM REVEGETATION SUCCESS

RRTAC PROJECT

79-23-WEI

P.F. ZIEMKIEWICZ

SCIENTIFIC & ENGINEERING SERVICES

ALBERTA ENERGY AND NATURAL RESOURCES

JANUARY 1984

Species Selection and Fertilization

in Alpine & Subalpine Revegetation

(RRTAC Project #79-23-WEI)

ABSTRACT

Three test plots (one at Caw Creek Ridge and two at the Cadomin mine site) were established to evaluate the fitness of selected native and agronomic grass species to disturbed alpine and subalpine environments in the Eastern slopes of the Rocky Mountains in Alberta. Included in the study were the selected lines of nine native and four commercially available grass species. The alpine test plot was established on unamended spoil while the subalpine plots were established on both raw spoil and spoil capped with topsoil. Maintenance fertilization terms of from one to four years duration were also assessed to estimate fertilization requirements as a function of species and topsoil treatment.

INTRODUCTION

Surface mining, mineral exploration, oil and gas development, forestry, recreation and transportation disturb extensive areas in the Mountains & Foothills. These are the headwaters of Alberta's principal watersheds and the mountain streams are valuable fisheries. Therefore erosion control is the initial objective of most land reclamation programs. The natural rate of recovery of these disturbed areas by plant colonization and succession is extremely slow and may require many decades or even centuries.

In many cases topsoil can be removed and replaced over mine spoil to enhance its plant growth potential. In other cases there is no salvageable topsoil and nutrients must be added by fertilization.

Some commercially-available agronomic grasses grow well over much of the Mountain and Foothill environment. However, these species do poorly on exceptionally harsh sites. These include alpine and upper subalpine areas, sites with unamended coarse spoil, high wind and sunlight exposure. In 1976 D.G. Walker, of the University of Alberta proposed to develop selected high elevation grasses for reclamation purposes. The proposal was supported by the Alberta Government and Parks Canada. The objective was to develop native grasses which would provide erosion control and forage on harsh sites with minimal management (e.g. fertilization, reseeding, surface amendment). Wild grasses were initially selected on their ability to invade Alpine and Subalpine disturbances.

Specimens were then grown near Edmonton and selected on the basis of their cultural attributes: seed production and viability, disease resistance, vigor and uniformity of maturity.

By early 1979 this program had produced nine selected lines of native grass species. To ensure that the selected lines had not lost their tolerance to high-elevation conditions in the process of selection, a series of test plots was established:

1) to evaluate the fitness of selected lines of various native grass species to Alpine and Subalpine environments in the Eastern slopes of Alberta, and

2) to study the response of native grass species to the application of fertilizer,

3) to compare the performance of the native grasses and commonly used agronomic grasses.

MATERIALS & METHODS

The plots were established on September (14-17), 1979. One test plot involving no topsoil treatment was established at Caw Creek Ridge (Alpine) and two test plots, one with and another without topsoil treatment, were established at the abandoned Cadomin Mine site (Subalpine).

Description of Study Areas

(a) **Caw Creek Ridge (Alpine)** The study area is located near Grande Cache, Alberta (NW¼ 35-58-10 W6M) at an elevation of 1901 m and was once accessible by four-wheel drive vehicle under favourable weather conditions. The site is a former drilling pad and consists of a flat surface covered with broken and recently weathered shale. Rocks and pebbles of varying sizes dominate the site. The study area has been fenced in order to minimize disturbance. The soil sample taken from the area was analyzed by the Alberta Agriculture, Soil Testing Laboratory and the results are presented in the Appendix.

(b) **Cadomin Mine Site (Subalpine)** The study area is located in the Rocky Mountain Foothills of west-central Alberta (S½ 32-46-23 W5M) at an elevation of 1675 m. This former open-pit coal mine is 1.6 km south east of Cadomin, Alberta and is accessible by four-wheel drive vehicle. The site is characterized by flat-topped spoil-heaps consisting mainly of sandstone, silstone, and shale overburden. The study area is fenced.

Experimental Design The effects of four fertilization regimes on the growth of thirteen species were tested in a 4 x 13 factorial randomized block design with three replications. The same experimental design was implemented at both Caw Creek Ridge and Cadomin mine sites (see Appendix for details of experimental design and plot layout).

A commercial brand of inorganic fertilizer (Diammonium phosphate) yielding 18-46-0 was applied in early June from 1980 through 1983 to all three test plots. The rate of fertilization was 150 kg/ha or 15 g/m^2. The fertilizer was applied to an area of about 15 cm on either side of (1 m long) furrows. Maintenance fertilizer application periods of from one to four years comprised the fertilizer treatments. By 1983, the fourth year of the study, all four fertilizer treatments had been applied.

The native seed used in the experiment was grown at the Genetics Field Laboratory of The University of Alberta at Ellerslie and harvested in 1978. With the exception of Poa interior, the seed sample of each of the native species used was composed of a mixture of two or more improved lines (multiline) selected in 1978 (for sources of different lines, see Appendix). The four commercial varieties of grass species used in the study were obtained from local seed distributors.

Seeds were sown by hand in a 1 m long furrow. The depth of seeding varied from 1-2 cm. Immediately after planting, seeds were covered with soil. Each furrow was marked with a metallic label indicating the randomization code numbers. Information on seeding rate, weight of 1000 seeds and seed germination percentages of various grass species used in the study is given in the Appendix.

The grass species were seeded in September 1979 and the performance of these species was assessed in mid August from 1981 to 1983. In

assessing species performance three parameters were of interest: 1) Aerial Cover, 2) Flowering and 3) Seed Head Shattering. Aerial Cover was estimated using a horizontal $1m^2$ grid with 10 cm^2 divisions. The seeds had been planted in 1m long furrows to minimize interplot competition and fertilizer movement. Therefore the data reflect the degree to which each species colonized first the furrow and then the surrounding area. The following formula very roughly translates the Aerial Cover data into % ground cover:

$$\% \text{ Cover} = (100\ cx)\ (500\ vld)^{-1}$$

where: c = Aerial Cover (cm^2)

x = Seeding Rate (Seeds/Linear 100 cm)

d = distance between drill Rows (cm)

l = Plot length (cm)

v = Seed Viability (%)

The constant 500 represents the seeding rate (per linear meter) used in this study.

Unless a species produces propagules on a site it will ultimately die out. High elevation sites with their short growing seasons restrict reproduction in many commercial grass species. As part of species performance assessment flowering and shattering were recorded for each plot during 13-15 August of 1981, 1982 and 1983.

RESULTS

Extremely windy conditions combined with the coarse spoil to contribute to the poor establishment of the grasses at the subalpine

no topsoil site. This site was chosen because of its harshness and the results therefore, are not representative of grass establishment on most untopsoiled mountain spoils. Winds of 150 km/hr have been recorded at the site and in the year after seeding the surface had deflated leaving a pavement of ironstone and shale fragments. Individual ironstone fragments roughly 1 cm^3 and larger had, in fact, been blown up to half way (6m) across the adjacent topsoiled plot. Presumably much of the seed traveled even farther. On the finer textured alpine and topsoiled subalpine sites seedling establishment was generally effective and no wind erosion was evident.

1. Aerial Cover

Two key objectives of revegetation in the mountains are erosion control and forage production. The former is the first priority so each species was rated on its capacity to quickly generate ground cover. Species selection and fertilizer regime were both found to significantly affect cover. The species by fertilizer interaction was significant only at the alpine site suggesting that in the subalpine the native and agronomic species responded similarly to fertilization (Table 1).

(a). **Species Selection**. The native Agropyrons: trachycaulum, dasystachyum, latiglume and subsecundum consistently produced the most aerial cover. The other natives: Trisetum spicatum, Poa interior, Poa alpina, Festuca saximontana and Deschampsia cespitosa fared poorly on the subalpine sites. However, Poa interior, Poa alpina and Festuca saximontana were among the best performers at the alpine site, (Figures 1, 2).

Table 1 - Analyses of Variance for Aerial Cover Data

n	Source of Variation	Degrees of Freedom	'F' Test		
			Subalpine No Topsoil	Subalpine Topsoil	Alpine
3	Reps	2			
13	Spp.	12	9.0*	28*	3.3*
4	Fert.	3	12.9*	8.6*	62.7*
	SXF	36	1.4	1.4	2.4*
	Error	102			
156	Total	155			

* = Significant at 95% Confidence Level

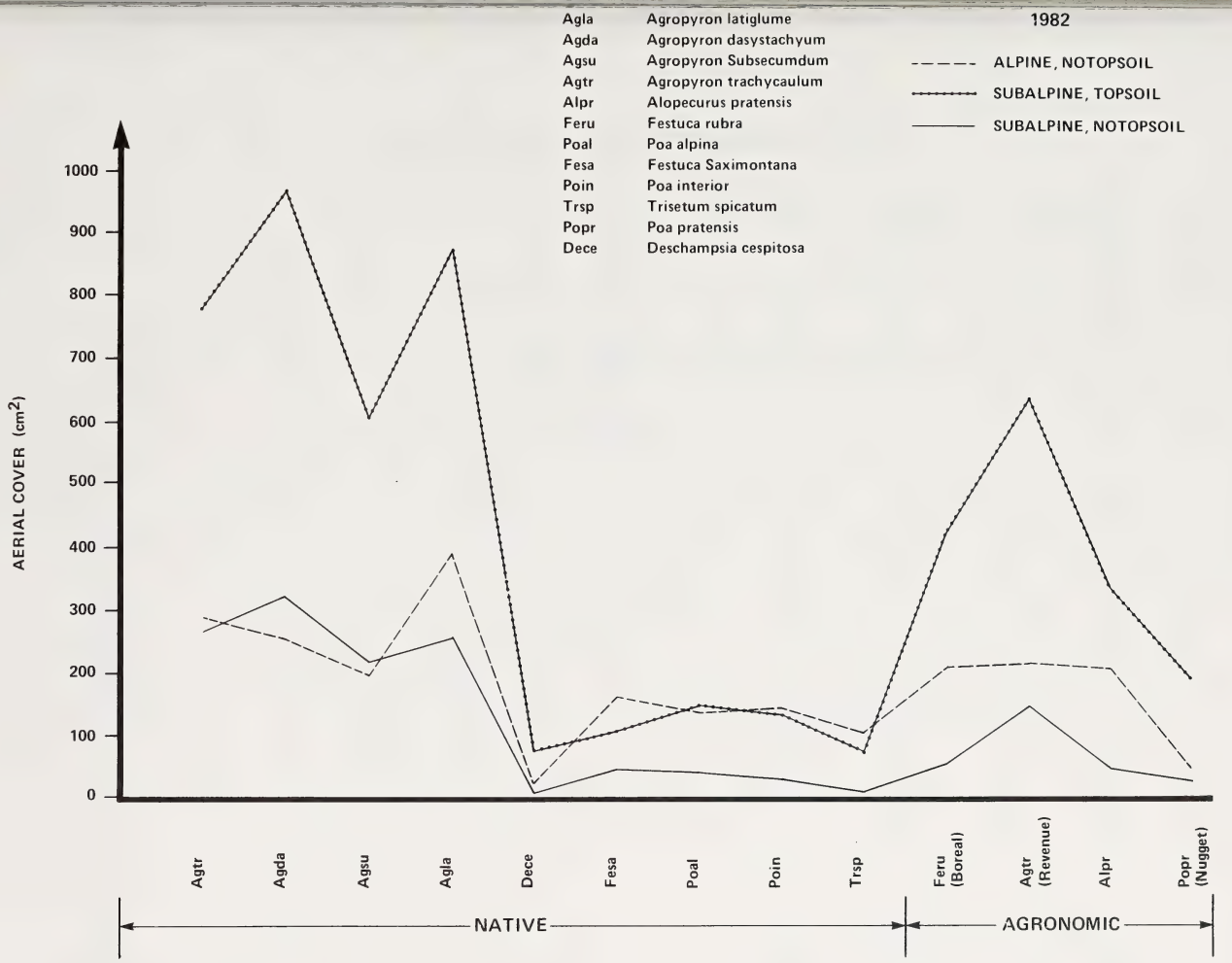


Figure 1. Aerial Cover Development by the 13 Grasses in 1982

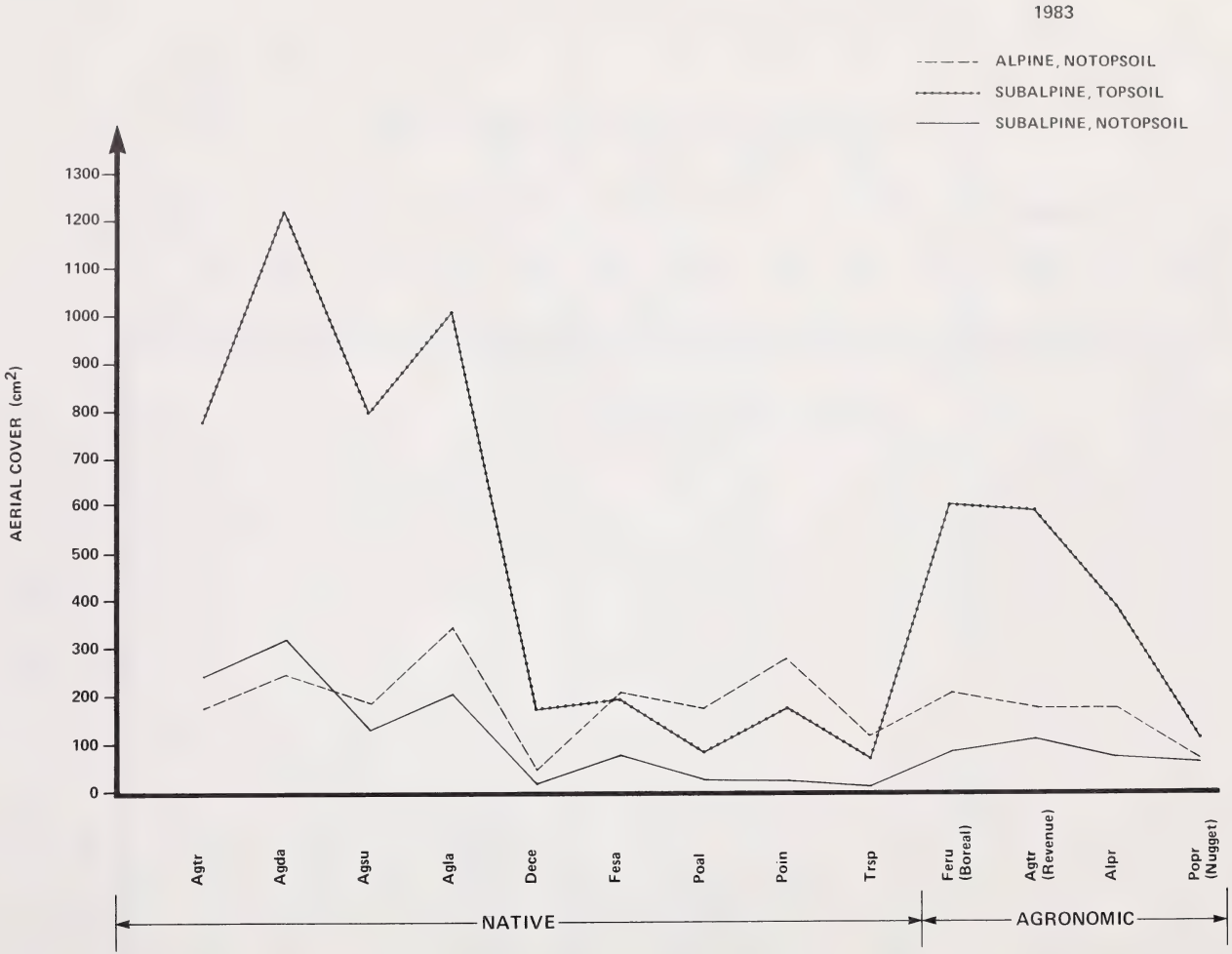


Figure 2. Aerial Cover Development by the 13 Grasses in 1983

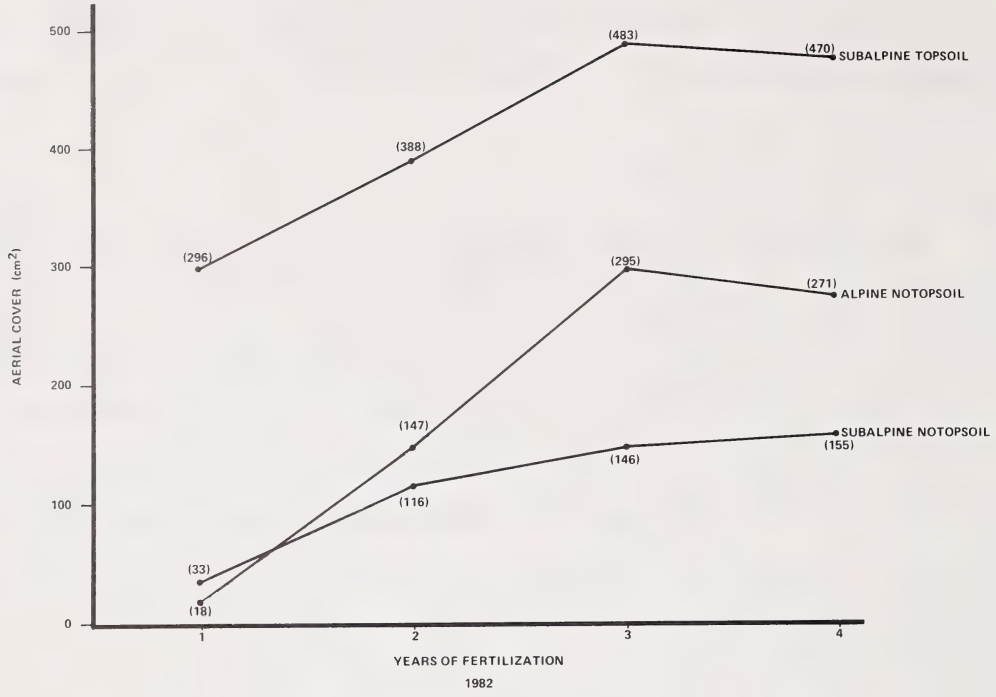
Among the agronomic grasses Festuca rubra (c.v. Boreal) and Agropyron trachycaulum (c.v. Revenue) were superior in terms of cover production.

(b) **Fertilization**. Fertilization had a strong effect at each site. The effect of the yearly fertilization was cumulative on the no topsoil sites but seems to have levelled off after three years at the topsoiled site (Figure 3). The fertilization by species interaction demonstrates this clearly (Figures 4, 5, 6). Also, die-back on the no topsoil sites occurred annually after cessation of fertilization while on the topsoiled site growth continued to be strong after maintenance fertilization was terminated (Figure 7).

2. Flowering and Shattering

The tendencies for a grass to flower and particularly to undergo seed head shattering by August were regarded as indicators of its reproductive potential. Reproduction by seed will be necessary by all of the test species except for the rhizomatous Agropyron dasystachyum. There was no attempt to collect and test the viability of seed produced on the plots.

Agropyron latiglume and A. trachycaulum consistently displayed high rates of flowering and shattering in the subalpine while Agropryon trachycaulum (c.v. Revenue) shattered in only 8% of the subalpine plots.



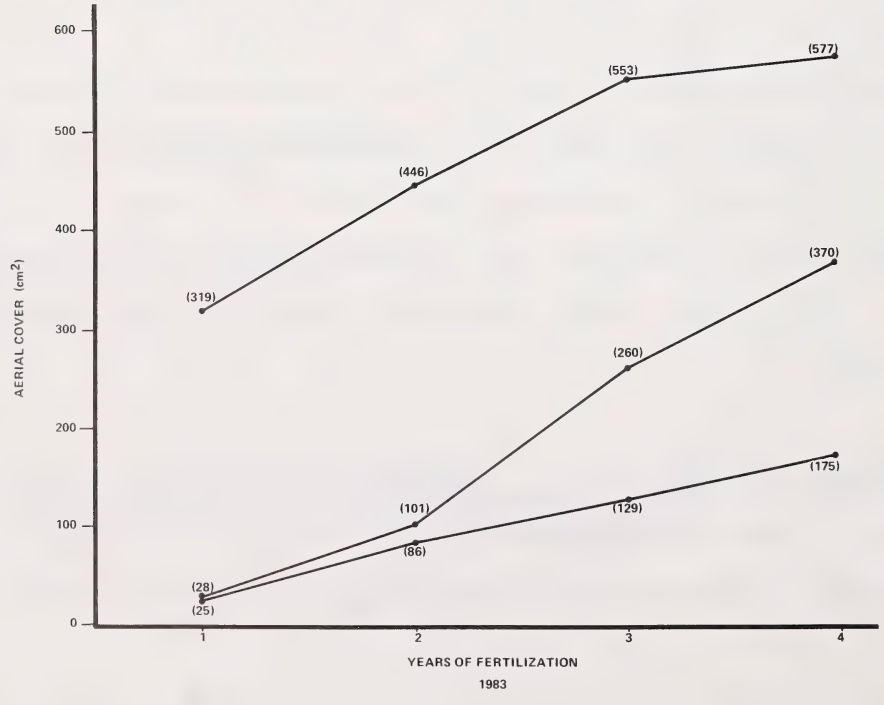


Figure 3. The effect of Fertilization, Site and Topsoil on Aerial Cover in 1982 & 1983. The Initial Fertilization Occurred in 1980

SUBALPINE NO TOPSOIL 1983 (CADOMIN)

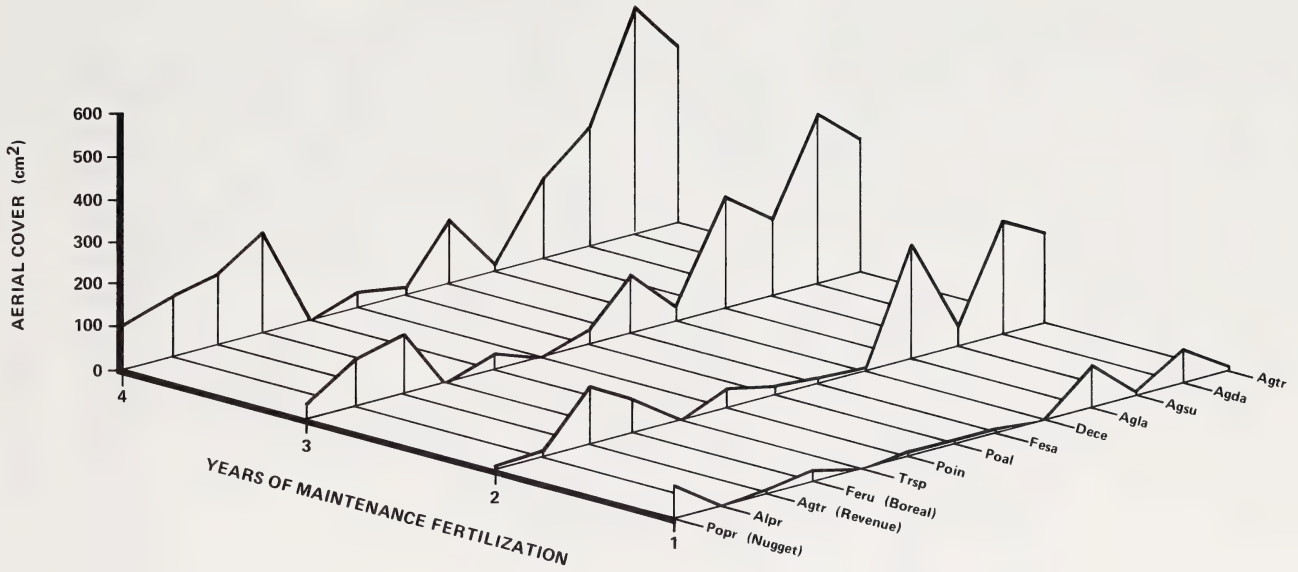


Figure 4. The Response of 13 Grass Species to One to Four Years of Maintenance Fertilization at the Subalpine No Topsoil Site

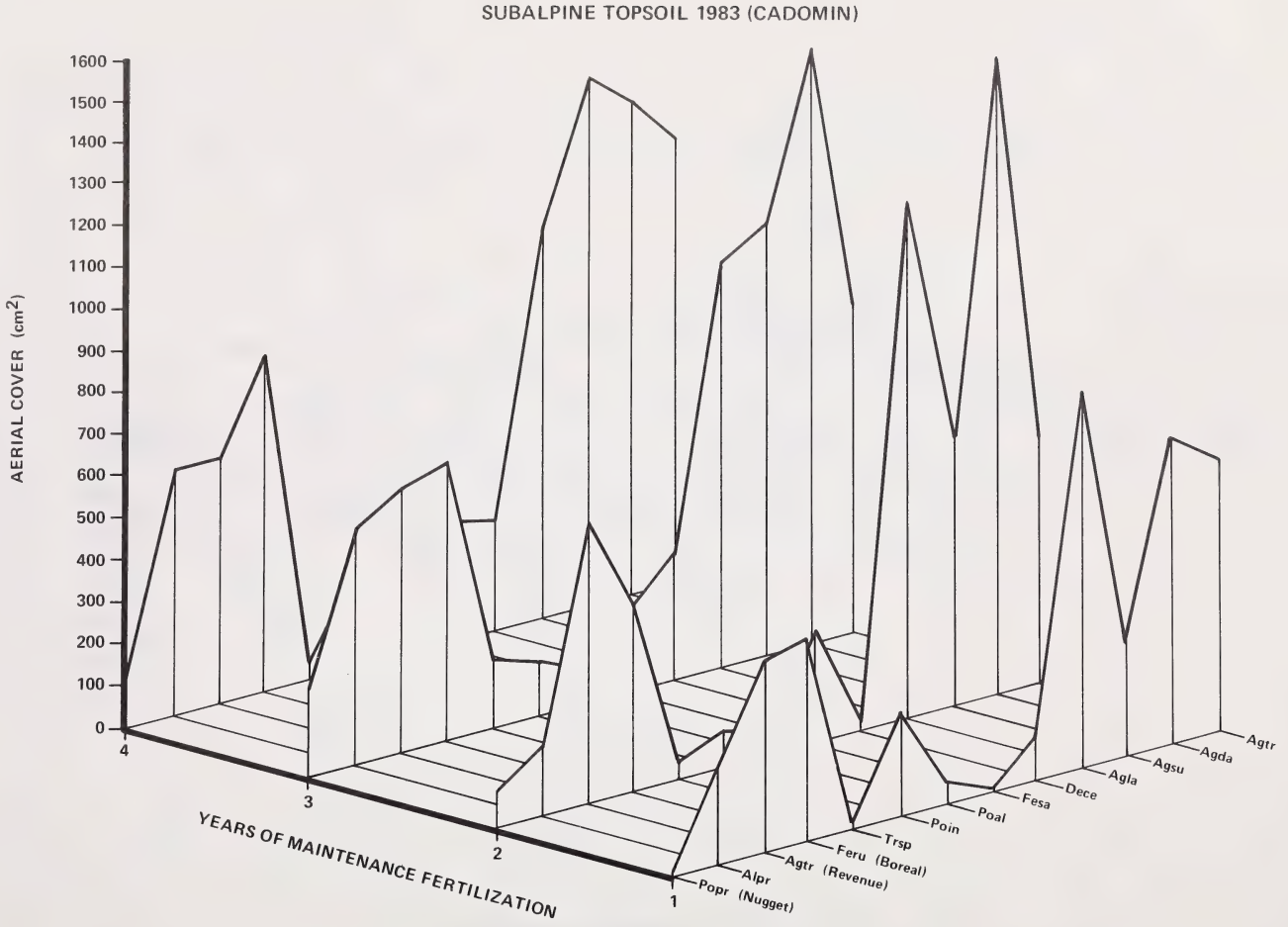


Figure 5. The Response of 13 Grass Species to One to Four Years of Maintenance Fertilization at the Subalpine Topsoiled Site

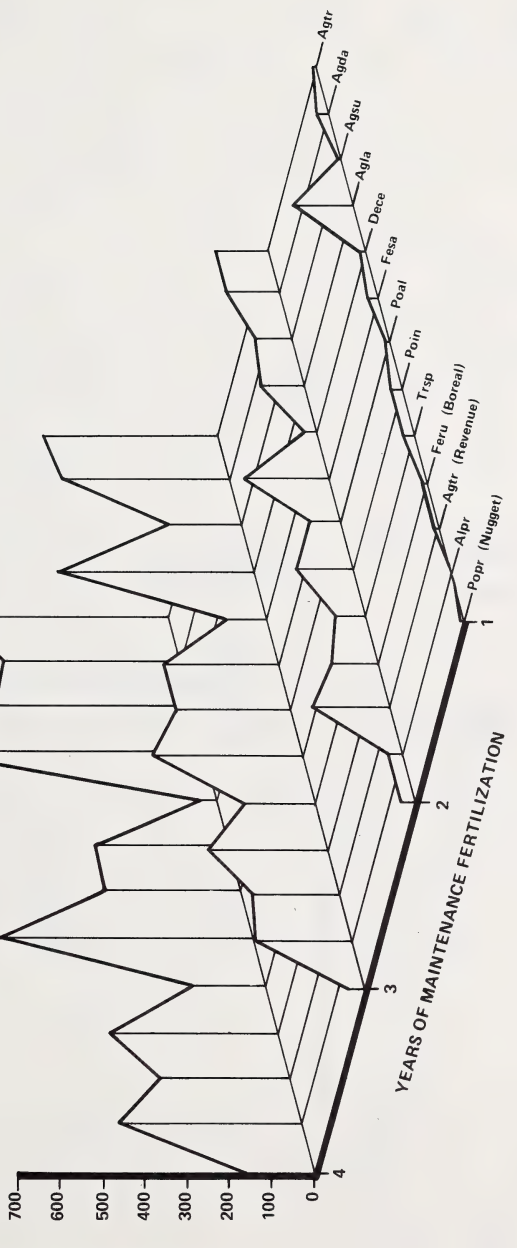


Figure 6. The Response of 13 Grass Species to One to Four Years of Maintenance Fertilization at the Alpine Site

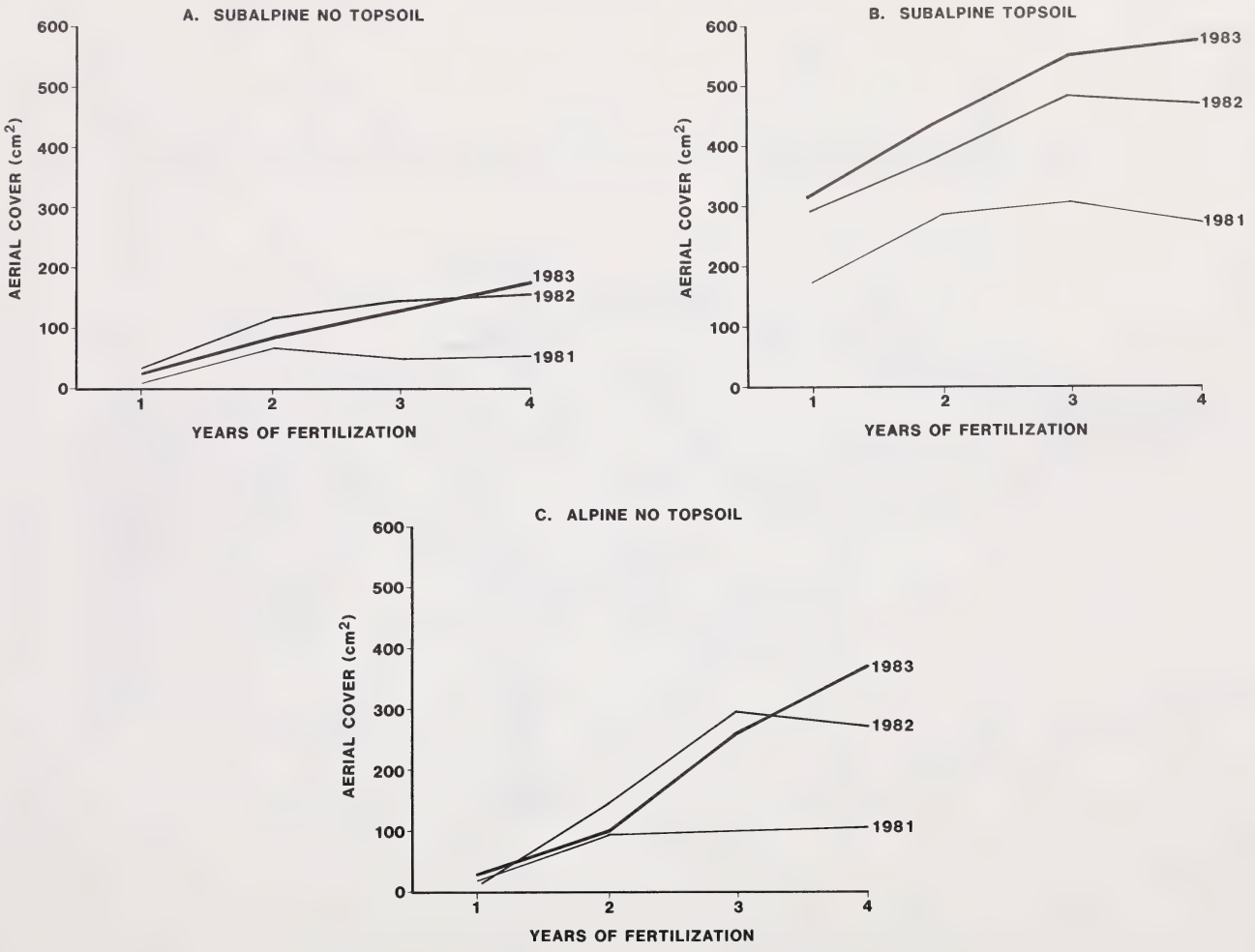


Figure 7. Aerial Cover on the Three Test Sites Measured from 1981 to 1983 as a Function of Maintenance Fertilization

Although many of the small-seeded species did not establish during the first year the surviving individuals at Cadomin showed a strong tendency to flower and shatter (e.g., Festuca saximontana, Poa alpina, Poa interior and Deschampsia cespitosa). Only Agropyron dasystachyum failed to shatter on any site. This was in part compensated by its strong tendency to propagate via rhizomes. Other species with low reproductive potential were Agropyron subsecundum and Agropyron trachycaulum (c.v. Revenue). All species except Agropyron dasystachyum flowered at the alpine site. However, only Agropyron latiglume, Deschampsia cespitosa, Festuca saximontana, Poa alpina, Poa interior and Alopecuris pratensis had shattered by mid-August (Table 2).

CONCLUSIONS

Species Selection. Agropyron latiglume was perhaps the best grass tested since it was among the top cover producers on all sites and it showed excellent reproductive potential. Agropyron trachycaulum was also excellent though it never shattered in the Alpine. Agropyron dasystachyum and Agropyron subsecundum produced good cover but had low reproductive potential. In the case of Agropyron dasystachyum this was compensated by its strong rhizomatous tendency.

The other native grasses clearly had establishment problems at the subalpine site. Those plants which germinated and survived, however, continued to increase in cover and displayed strong reproductive potential.

Table 2 - Incidence of Flowering as a Function of Site, Topdressing and Species (% of Plots with Plants in Flower: % of Plots with Seeds Shattering) in the 3rd and 4th years of the experiment.

	SUPALPINE				ALPINE	
	Topsoil		No Topsoil			
	1982	1983	1982	1983	1982	1983
Agropyron trachycaulum	100:92	100:25	75:42	75:42	42:0	58:0
A. dasystachyum	92:0	83:0	58:0	42:0	0:0	0:0
A. subsecundum	100:0	100:17	75:8	75:25	8:0	8:0
A. latiglume	100:92	100:100	83:83	100:00	67:8	58:0
Deschampsia caespitosa	50:50	83:83	0:0	8:8	0:0	33:33
Festuca saximontana	75:50	75:66	50:50	50:50	67:50	83:0
Poa alpina	92:83	100:100	33:33	42:42	58:25	91:0
Poa interior	83:75	83:83	8:8	33:33	67:0	75:8
Trisetum spicatum	33:33	50:50	8:8	8:8	33:0	75:0
Festuca rubra (Boreal)	92:25	91:91	42:8	25:25	25:0	66:0
A. trachycaulum (Revenue)	100:0	100:8	58:8	50:0	0:0	0:0
Alopecurus pratensis	83:50	75:66	8:8	17:17	33:8	17:0
Poa pratensis (Nugget)	75:58	83:83	33:33	17:17	8:0	50:0

None of the Agronomic grasses produced as much cover as the native Agropyrons on the subalpine sites. The Agronomic and native grasses generated similar cover levels on the alpine site though the native grasses had a greater reproductive potential.

Based on cover development and reproductive potential of the tested grasses three conclusions may be drawn regarding species selection.

1. On subalpine sites the native Agropyron trachycaulum, A. subsecundum and A. latiglume would be the best grasses for reclamation.

2. On alpine sites Poa interior, Festuca saximontana and Agropyron latiglume would be best.

3. The Agronomic grasses Festuca rubra, Agropyron trachycaulum (c.v. Revenue) and Alopecuris pratensis all provided good levels of cover on the subalpine and alpine sites. The reproductive potential of Agropyron trachycaulum (c.v. Revenue) was almost nil, however, and Alopecuris cover dropped off sharply two years after maintenance fertilization stopped. Festuca rubra, therefore, is the recommended agronomic grass both in the subalpine and alpine.

Fertilization

Plant cover was enhanced by maintenance fertilization. Except for species which failed to become established, cover was invariably highest on plots fertilized in the assessment year. On non-topsoiled

sites dieback was a common occurrance in the years following fertilizer withdrawal. This tendency was general though it appeared most strongly pronounced in Alopecuris pratensis and Agropyron subsecundum. The effect of fertilizer withdrawal was not observed in many species for two years. The trend, on unamended spoil without legumes however, seems to be continuous and downward.

Topsoil

No dieback occurred on topsoiled plots. Cover continued to increase even on plots which had only been fertilized once. This suggests that after the initial fertilization topsoiling provides adequate nutrients for the establishing grass cover. One or two years of fertilization would be recommended to accelerate the rate of cover development and to minimize erosion. Afterwards no further fertilization should be required.

Appendix 1

AGRICULTURAL SOIL AND FEED TESTING LABORATORY

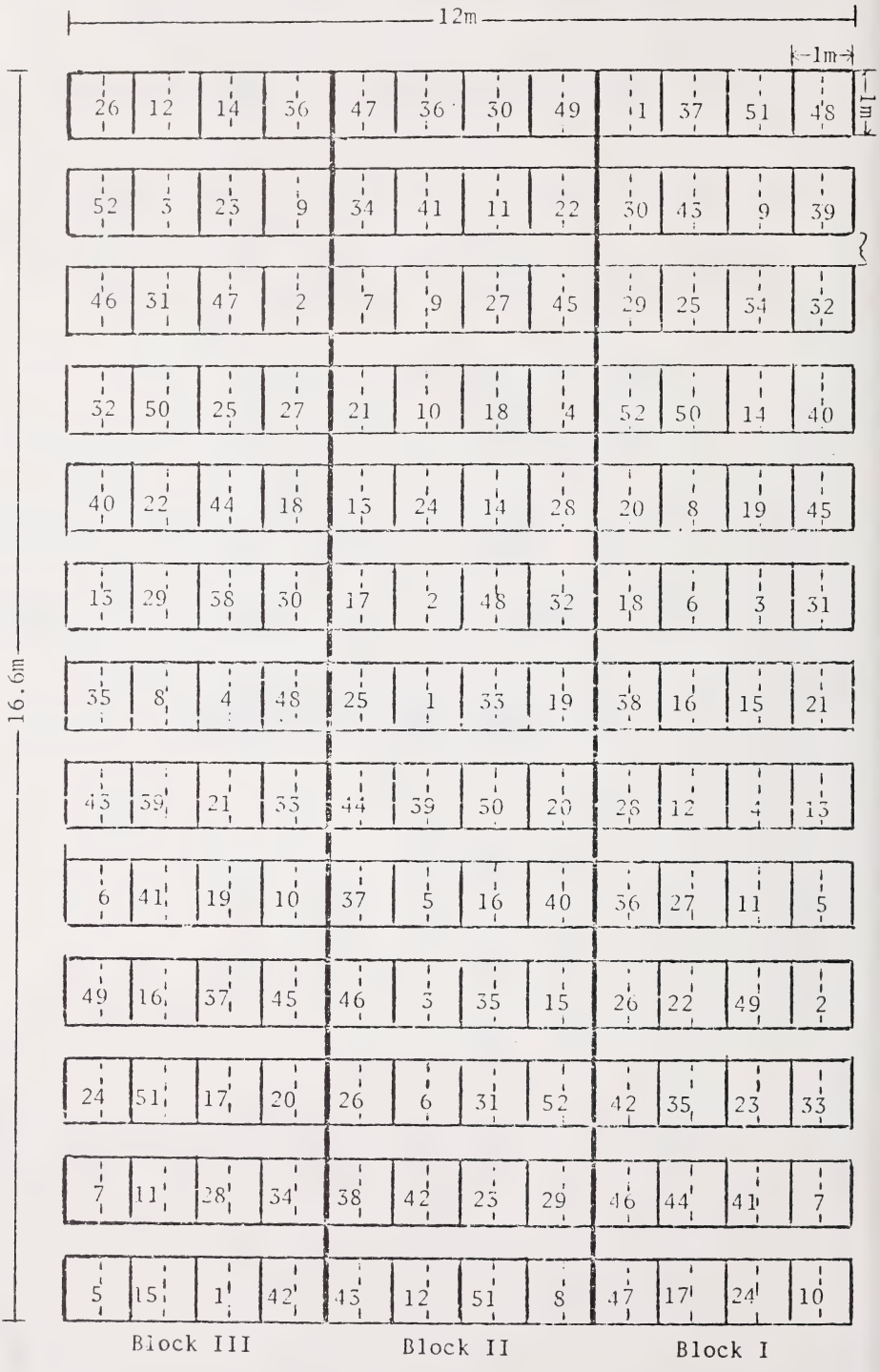
TEST RESULTS ON SOIL SAMPLES

B 45500
Date: 1/2/80

Plot No.*	(N)	(P)	(K)	(Na)	(S)	(ph)	Conductivity mmhos.	Sulfate SO_4	Org. Matter	Free Lime $CaCO_3$	Texture
1	2	1	178	L-	M-	8.5	0.2	---	M	---	2
2	5	4	145	L-	L+	7.6	0.2	---	L	---	2
3	2	1	112	L-	M-	8.1	0.2	---	L+	H-	3

* 1 Cadomin Mine Site Overburden
  2 Cadomin Mine Site Topsoil
  3 Caw Creek Ridge Soil Sample

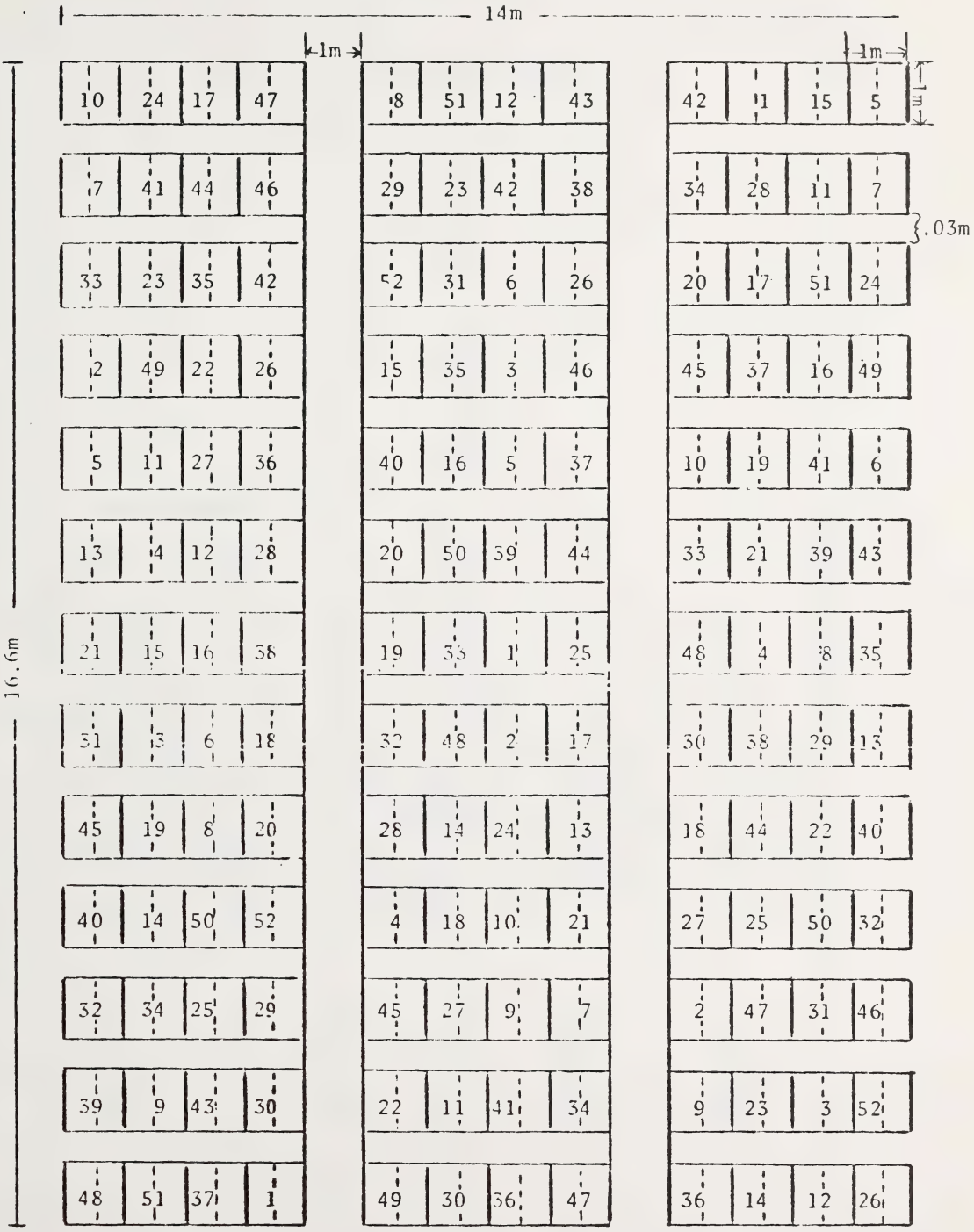
Experimental design used for establishing test plots at Caw Creek Ridge and Cadomin.



NOTE: 1) Broken lines within $1m^2$ plots represent direction of furrows.

2) See Key to Species (Tables 2-4) for explanation of code numbers used in different blocks.

Experimental design used for establishing test plots at Cadomin. The same layout was used on raw overburden and on topdressed overburden.



NOTE: 1) Broken lines within $1m^2$ plots represent direction of furrows.

2) See Key to Species (Tables 2-4) for explanation of code numbers used in different blocks.

Appendix II Cont'd.

Randomization

Code	Species/Years of fertilization
1	1/1
2	2/1
3	3/1
4	4/1
5	5/1
6	6/1
7	7/1
8	8/1
9	9/1
10	10/1
11	11/1
12	12/1
13	13/1
14	1/2
15	2/2
16	3/2
17	4/2
18	5/2
19	6/2
20	7/2
21	8/2
22	9/2
23	10/2
24	11/2
25	12/2
26	13/2
27	1/3
28	2/3
29	3/3
30	4/3
31	5/3
32	6/3
33	7/3
34	8/3
35	9/3
36	10/3
37	11/3
38	12/3
39	13/3
40	1/4
41	2/4
42	3/4
43	4/4
44	5/4
45	6/4
46	7/4
47	8/4
48	9/4
49	10/4
50	11/4
51	12/4
52	13/4

Species Code

Selected Lines of:

1. Agropyron trachycaulum
2. A. dasystachyum
3. A. subsecundum
4. A. latiglume
5. Deschampsia caespitosa
6. Festuca saximontana
7. Poa alpina
8. Poa interior
9. Trisetum spicatum

Commercial Lines of:

10. Festuca rubra (Boreal)
11. A. trachycaulum (Revenue)
12. Alopecuris pratensis
13. Poa pratensis (Nugget)

Appendix III Grass species seeded at Caw Creek Ridge and Cadomin

Species Code	Genus and Species	Source	Approx. No. of seeds/1m furrow	1000 seed wt. (g.)	% Germination (lab. test)
	Native Species				
1	**Agropyron trachycaulum**	Multiline Selection (1978) derived from: Grassy Mountain, Waterton Flats, Smoky River, Barnaby Ridge, Mountain Park, Sheep River	500	4.28	92
2	**Agropyron dasystachyum**	Multiline Selection (1978) derived from: Kootenay Plains, Sheep River, Mount Stearn, Cat Creek, Ya Ha Tinda, Athabasca Ranch	500	4.00	93
3	**Agropyron subsecundum**	Multiline Selection (1978) derived from: Greenock Mountain, Athabasca Ranch, Smoky River, Rock Lake	500	4.48	92
4	**Agropyron latiglume**	Multiline Selection (1978) derived from: Mountain Park, Caw Creek Ridge	500	4.80	91

Appendix III (cont'd)

Species Code	Genus and Species	Source	Approx. No. of seeds/1m furrow	1000 seed wt. (g.)	% Germination (lab. test)
5	**Deschampsia caespitosa**	Multiline Selection (1978) derived from Marmot Parkers Ridge Beartooth Hwy., Montana	500	0.30	85
6	**Festuca saximontana**	Multiline Selection (1978) derived from: Mountain Park Coal Valley Pyramid Lake	500	0.72	91
7	**Poa alpina**	Multiline Selection (1978) derived from: Grassy Mountain Coal Valley Barnaby Ridge Mountain Park Snow Creek Sunshine	500	0.56	55
8	**Poa interior**	Selected Line (1978) derived from: Whistlers Mountain	500	0.36	79
9	**Trisetum spicatum**	Multiline Selection (1978) derived from: Cat Creek Coal Valley Grassy Mountain	500	0.24	85

Appendix III (cont'd)

Species Code	Genus and Species	Source	Approx. No. of seeds/1m furrow	1000 seed wt. (g.)	% Germination (lab. test)
	Commercial Lines				
10	**Festuca rubra**	Commercial variety: Boreal	500	1.20	74
11	**Agropyron trachycaulum**	Commercial variety: Revenue	500	4.20	92
12	**Alopecuris pratensis**		500	0.80	89
13	**Poa pratensis**	Commercial variety: Nugget	500	0.50	

MAINTENANCE FERTILIZATION OF A REVEGETATED SUBALPINE COAL MINE SPOIL[1]

S.K. Takyi and M.R. Islam[2]

ABSTRACT

In an earlier study, a coarse and very nutrient-poor calcareous coal mine spoil in a subalpine environment was revegetated artificially through fertilization to a grass cover. After 26 years following mine abandonment the spoil had not regenerated naturally. The earlier study was modified in an attempt to determine an appropriate maintenance fertilization program.

Two years after maintenance fertilization of the original study was discontinued, productivity, estimated as percent plant cover and yields, had declined drastically. In the first year of the resumption of maintenance fertilization (at different rates scheduled in three-year cycles) the level of productivity restored was considerably less than that achieved in the year fertilization was discontinued. Analyses for available plant nutrients in the spoil seven years after it was revegetated artificially indicated no reserves of available nitrogen had been built up; this also was reflected in the low amounts of nitrogen uptake. Available phosphorus had increased only very marginally even in this calcareous mine spoil, and the available potassium levels following years of maintenance fertilization were rather erratic.

Generally, in the short term, it may be concluded that seven years after plant cover establishment there is a virtual absence of residual fertilizer influence from the previous years of maintenance fertilizations on current cover productivity; and there has been very little decomposition of the accumulated litter from previous years to suggest any nutrient cycling to ensure a self-sustaining plant cover at this stage.

---

1 Presented at the 21st Annual Alberta Soil Science Workshop, Lethbridge Alberta. February 19 and 20, 1985. This paper is published as part of these proceedings with the permission of the organizers of the Workshop at Lethbridge.

2 Alberta Energy and Natural Resources, Edmonton, Alberta, T5K 2M4

INTRODUCTION

Most drastically-disturbed lands in a subalpine environment are sometimes difficult to reclaim. In establishing vegetation on drastically-disturbed sites, such as in surface mining for coal in the Eastern Slopes of the Rocky Mountains in Alberta, the lease holder may be faced with the challenge of maintaining an adequate and vigorous plant cover over the long term. To meet this challenge the lease holder often resorts to management inputs, such as fertilization, to maintain acceptable levels of plant growth. The bigger challenge is to ensure that once such management inputs are stopped, a self-sustaining plant community remains. A self-sustaining plant community essentially implies that nutrient cycling has been restored in the system. The situation is of concern to the lease holder because it is expensive to manage reclaimed areas for long periods, because certain legal obligations have to be met, and because some unenforceable commitments to society must be addressed.

The results of a six-year study on an abandoned strip coal mine near Cadomin ($S\frac{1}{2}$ of 32-46-23-W5M) in a subalpine environment showed that the cultivated grass cover established on the mine spoil cannot sustain a vigorous optimum plant cover without some plant nutrient inputs for a considerable length of time. The current study, which was started last year, is attempting to address the long-term vegetation maintenance problem through a change in the focus of the original study. The main objective of the refocused study is to determine the optimum frequency of fertilization for an extended maintenance of the site following the initial successful establishment of a grass cover.

MATERIALS AND METHODS

The mine spoil is composed of materials containing calcareous sandstones, siltstones, shale and coal fragments. It is characterized by high infiltration rate and low moisture content during any extended precipitation-free period. There is very little soil fraction (2 mm) in the surface 15-cm layer. In addition to other climatic constraints, the growing season precipitation distribution in the area could be rather uneven.

The original trial was laid out in June, 1978 with the objective of establishing plant cover on the spoil which had not naturally revegetated 26 years after mine abandonment. A randomized complete block design with three replications was used. Four seeding rates (30, 60, 90 and 120 kg/ha) and five fertilizer treatments were tested. Fertilizer treatments (N-P-K) were 0-0-0, 40-20-40, 60-30-60, 80-40-80, and 80-40-80 (split) kg per ha. Nitrogen was applied as urea and 10-30-10, phosphorus as 10-30-10, and potassium as KCl and 10-30-10. The cultivated grass/legume mixture seeded consisted of creeping red fescue, Canada bluegrass, timothy and white clover. The plots received maintenance fertilizers annually till 1981. Unfertilized (control) plots developed virtually no plant cover. No maintenance fertilization was carried out in 1982 and 1983.

In June, 1984 alfalfa (rambler) was broadcast at 3 kg/ha to each plot in an attempt to re-establish a legume because the white clover seeded in 1978 had virtually died out by 1980. In the same year (1984) the original trial was modified and fertilization became the only treatment because after six years the seeding rate treatments consistently showed no significant differences. The fertilizer treatments involved varying rates and application intervals (yearly, once every two years, once every three years, and a control). Fertilizer treatments, were 40-20-40, 60-30-60, 80-40-80, the same as originally applied in 1978; and 60-0-0 (no fertilization since 1978), and 60-0-0 (80-40-80, split applied in 1978), and a no fertilizer control. The fertilizers were broadcast as 34-0-0 (S-free) and 6-24-24.

Percent plant cover and aerial biomass yields were assessed along with other plant growth parameters. Percent plant cover of the above ground living vegetative cover was estimated using a quadrat. Living biomass was collected from randomly-placed 0.25 m quadrats by clipping at 4 cm above ground surface. The dried (65°C for 48 hours) biomass samples were weighed and submitted to a commercial laboratory for chemical analyses. The spoil samples were also analysed by the same laboratory.

RESULTS AND DISCUSSION

The study discussed in this paper has run only one year of the three-year planned maintenance fertilization cycles. Results of the first year showed some significant responses to fertilization following two years without maintenance fertilization.

The chemical properties of the spoil are discussed by Russell and Takyi (1979). A tabulated summary of some properties of the spoil is given in Table 1. The spoil has a pH of over 8.0 because the materials in the area are mostly calcareous in nature. It is low in available plant nutrients. This perhaps partly explains the very sparse natural regeneration in most areas nearly three decades after mine abandonment. The available ammonium form of nitrogen was higher than would be expected in the spoil. The total nitrogen content of the coal in the spoil is high, about 1.5 percent. Perhaps some of this total nitrogen is readily extracted by KCl solution. Observations in plant growth vigor in unfertilized plots indicate that this extractable ammonium nitrogen has not been readily available to the seeded plants growing on the unfertilized spoil.

Table 1. Some Properties of the Mine Spoil[1]
(from Russell and Takyi, 1979)

Available Nutrients, kg/ha				TEC	pH	EC
NH_4-N	NO_3-N	P	K	me/100g		mS/cm
12	0	0	(166)	6.6	8.8	0.3

[1] 29% of the spoil is 2 mm or less in size. Of this, 77.2% is sand, 12.8% is silt, and 10.0% is clay.

In the two years of no maintenance fertilization of the successfully-established plant cover, productivity of the plant cover declined drastically (Table 2). The control had produced virtually no plant cover and yields through to 1983. The mean percent plant cover in the fertilized plots had declined by a factor of over four in the two years that maintenance fertilization was discontinued. The decline in biomass

yields over the same period was by an even higher factor. Poor relationship between percent plant cover and yields is the result of overestimation of the percent plant cover. Overestimation is known, through experience, to be influenced by the accummulated plant litter from preceding years. In 1981, the last year of fertilization, and in 1983, the second year after maintenance fertilization was discontinued, percent cover and yields were best in the treatments which received the two higher fertilizer doses.

Table 2. Effects of Fertilizer on Plant Cover and Yield Prior to Imposing Long-Term Maintenance Fertilizer Treatments in 1984[1]

	Fertilizer Treatments, N-P-K, kg/ha				
	0-0-0	40-20-40	60-30-60	80-40-80	80-40-80 Split Applied
Plant Cover, %					
1981 -	1	73	88a	93a	96a
1983 -	1b	12ab	21a	23a	25a
Yield, kg/ha					
1981 -	0[2]	3260b	4576ab	5464a	4816ab
1983 -	0b[2]	80ab	232a	136ab	not measured

[1] Fertilized from 1978 to 1981. Not fertilized in 1982 and 83.

[2] Growth too poor to be clipped.

Means in a given row followed by the same letter are not significantly different, p=0.05 (D.M.R.T.).

The drastic decline in productivity only two years after maintenance fertilization was discontinued is attributable to the available nutrient deficiencies in the spoil, particularly nitrogen, as the deficiency symptoms of this nutrient were very evident. This suggests a virtual absence of residual fertilizer influence or nutrient cycling, and after six years of plant growth and maintenance fertilization little nutrient reserves had built up in the spoil. Analyses of the spoil for available plant nutrients in the revegetated fertilized

treatments at the beginning of the seventh year (1984) confirmed that little plant nutrient reserves had accummulated (Table 3). Available nitrogen was still low in all treatments, but there was a very small accummulation of available P. The pH had decreased by about one-half unit (Table 3) in the highest fertilizer rate as compared with the initial level in 1978 (Table 1).

Table 3. Available Plant Nutrients and pH Levels in the Mine Spoil at Time of Fertilizing the Plant Cover in Spring, 1984

Fertilizer Treatment[1] N-P-K, kg/ha	Available Nutrients kg/ha				pH
	NH_4-N	NO_3-N	P	K	
0-0-0, Control	3	0	2	166	8.6
40-20-40	5	0	9	160	8.4
60-30-60	4	1	12	187	8.4
80-40-80	4	1	10	158	8.2
80-40-80[2]	4	1	13	223	8.2

[1] Not fertilized in 1982 and 83. Treatments in 1978, at the time plots were laid out.

[2] Split application.

With the resumption of maintenance fertilization in 1984, two years after the initial fertilization was discontinued, productivity measured as percent plant cover was somewhat restored when compared with the residual controls (Table 4). The treatment which had not received any fertilizer since 1978 had essentially not developed any plant cover, consequently the application of 60 kg N per ha made no impact on overall productivity because there were very few plants to start with. In the treatments which had received different fertilizer doses between 1978 and 1981 inclusive, and none up to and including 1984 (residual controls) the percent plant cover was in each instance lower than in the treatments with maintenance fertilization reinstated although the plots had the same fertilization history between 1978 and 1983.

Table 4. Effects of Fertilizer on Plant Cover and Yields in the First Year (1984)

Treatment N-P-K, kg/ha	Plant Cover, %	Yield, kg/ha
0-0-0[1], Control	1e	8d
60-0-0[1]	2e	88d
0-0-0[2*]	19bcd	256cd
60-0-0[2]	32ab	600ab
0-0-0[3*]	9de	128cd
40-20-40[3]	29abc	368bc
0-0-0[4*]	17cd	128cd
60-30-60[4]	24abc	520ab
0-0-0[5*]	19bcd	244bc
80-40-80[5]	36a	620a

[1] Not fertilized from 1978 to 1983.

Initial treatments in 1978 were: [2] 80-40-80 (split applied); [3] 40-20-40; [4] 60-30-60; [5] 80-40-80.

[2,3,4,5] Maintenance fertilized from 1979 to 1981 inclusive. Not fertilized in 1982 and 1983.

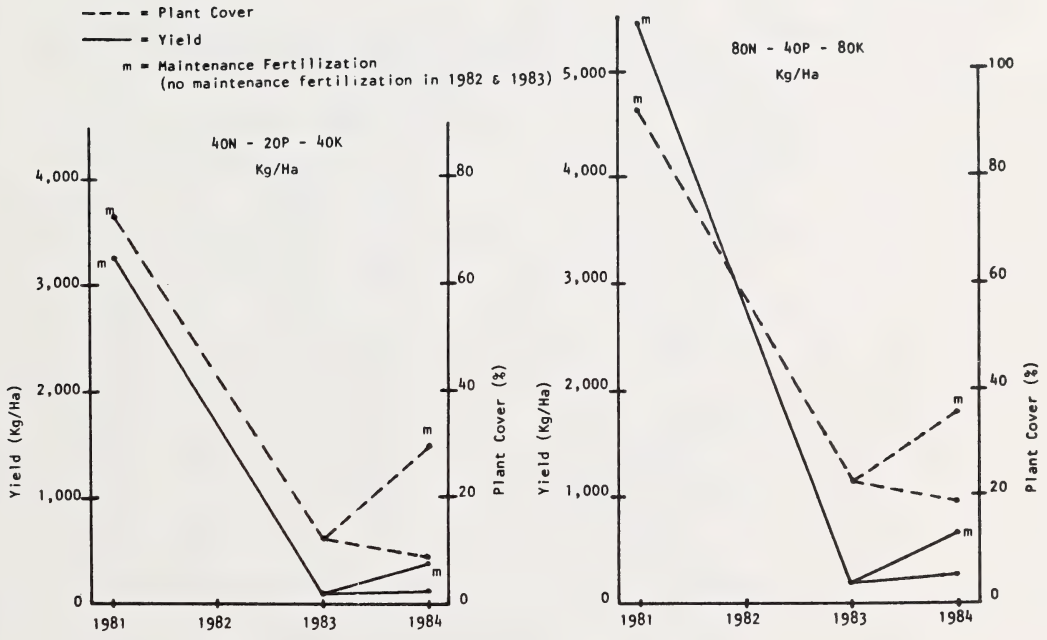
* Residual fertilizer control. Not fertilized in 1982, 1983 and 1984.

Means in a column followed by a common letter are not significantly different, p=0.05 (D.M.R.T.).

Improved productivity, measured also as yields, resulting from reinstated maintenance ferilization treatments in 1984 is summarized in Table 4. With the application of nitrogen alone to the treatment which had never been fertilized, yield improved to a certain, but not a significant, extent. In every other situation, where a good plant cover existed prior to discontinuation of maintenance fertilization after 1981, the reinstatement of maintenance fertilization resulted, in nearly all cases, significant yield increases. In no instance was the level of productivity achieved in 1981 approached in the year maintenance fertilization was reintroduced. It appears that once productivity was interrupted by withholding fertilizers it would take several years of maintenance fertilization to fully reinstate it on this spoil (Figure

1) with any of the fertilizer doses applied. Because a significant portion of the added fertilizers utilized by the plant cover in previous years is still tied up in the accumulated plant litter it could take several years of maintenance fertilization in such small doses to restore a level of productivity achieved earlier. In this situation, the high leaching losses of fertilizer nutrients from the coarse spoil should also be considered in maintenance fertilization.

Fig. 1: Changes in Plant Cover and Yields Between Maintenance Fertilizations



The analyses of the spoil for available plant nutrients at the end of the first season of growth in the year (1984) maintenance fertilization was reintroduced indicate very little if any nitrogen reserve had built up in any fertilizer treatment since 1978 (Table 5). This is to be expected because the accumulated plant litter has hardly begun to decompose and contribute to the nutrient pool in the spoil. Generally only small amounts of the nitrogen applied in the spring of 1984 remained in this coarse spoil in two months. It is expected that hardly any of the remaining nitrogen will be available to the plant cover in the

coming growing season because most of it will be lost through leaching. A very modest reserve of available P appears to have accummulated (Table 5), and the reinstated maintenance fertilization in 1984 has resulted in an additional small increase in the reserve. Available potassium levels in the spoil also show some increases; these increases are rather erratic. Overall, it could be summarized that nitrogen, which appears to be the most important nutrient in maintaining adequate growth of the plant cover on the spoil, remains at a critical level while available P appears to be accumulating only very slowly.

Table 5. Available Plant Nutrient Levels in the Mine Spoil at the End of the Growing Season in 1984

Fertilizer Treatment N-P-K, kg/ha	Available Nutrients, kg/ha			
	NH_4-N	NO_3-N	P	K
0-0-0[1], Control	9	2	3	130
60-0-0[1]	5	30	3	161
0-0-0[2*]	13	2	16	202
60-0-0[2]	16	13	18	293
0-0-0[3*]	11	2	10	123
40-20-40[3]	10	7	24	218
0-0-0[4*]	6	2	13	200
60-30-60[4]	8	7	27	232
0-0-0[5*]	13	2	14	135
80-40-80[5]	15	15	18	180

[1] Not fertilized from 1978 to 1983.

Initial treatments in 1978 were: [2] 80-40-80 (split applied); [3] 40-20-40; [4] 60-30-60; [5] 80-40-80.

[2,3,4,5] Maintenance fertilized from 1979 to 1981 inclusive. Not fertilized in 1982 and 1983.

* Residual fertilizer control. Not fertilized in 1982, 1983 and 1984.

Nitrogen concentrations and uptake of the plant growth in 1984 are summarized in Table 6. Concentrations were higher in the treatments which received new doses of fertilizers regardless of the fertilizer

treatment history of each treatment since 1978. The high nitrogen concentration in the control is attributable to the great distance between plants and that there was no competition for the little available N in the spoil. Nitrogen uptake was generally low because yields (Table 4) were also very low, particularly in the treatments which did not receive maintenance fertilizers in 1984. Results from the treatment which never received any fertilizers between 1978 and 1983 clearly indicate that a failed plant cover establishment, with only very few surviving plants, cannot be readily revived simply by applying an important plant nutrient such as nitrogen to the spoil. The nitrogen

Table 6. N Uptake and Concentrations in Plant Tops as Affected by Fertilization in 1984

Treatments N-P-K, kg/ha	Conc., %	Uptake, kg/ha
0-0-0[1*] Control	1.73	(0.1)
60-0-0[1]	2.77	2.4
0-0-0[2*+]	1.33	(3.4)
60-0-0[2]	2.39	14.3a
0-0-0[3*+]	0.48	(0.6)
40-20-40[3]	2.01	7.4
0-0-0[4*+]	0.75	(1.0)
60-30-60[4]	2.58	13.4a
0-0-0[5*+]	0.88	(2.1)
80-40-80[5]	2.49	15.5a

[1] Not fertilized from 1978 to 1983.

Initial treatments in 1978 were: [2] 80-40-80, (split applied); [3] 40-20-40; [4] 60-30-60; [5] 80-40-80.

[2,3,4,5] Maintenance fertilized from 1979 to 1981 inclusive. Not fertilized in 1982 and 1983.

* Plant samples from most 0-0-0 plots were very small. Reps were combined to provide adequate samples for chemical analyses. All these treatments were therefore excluded from the statistical analyses.

+ Residual fertilizer control. Not fertilized in 1982, 1983 and 1984.

Mean N uptake followed by a common letter are not significantly different, p=0.05 (D.M.R.T.).

uptake results reemphasize the results of the spoil analyses (Table 5) which indicate that in the seven years since plant cover was established on the spoil and maintained with fertilizers very little if any available nitrogen reserve had been built up, and, at least for a few more years yet, a good plant cover can only be maintained through the application of plant nutrients, primarily nitrogen.

CONCLUSIONS

The preliminary results of this study have shown that a discontinuation of maintenance fertilization for a duration of only two years of an artificially-revegetated low-nutrient mine spoil on stressful sites in the first few seasons of plant cover establishment leads to drastic decline in plant cover and yields. Upon the resumption of maintenance fertilization, it requires more than a growing season to restore the level of plant cover productivity achieved in earlier maintenance fertilization following the initial plant cover establishment.

A significant build-up of available plant nutrient reserves, especially nitrogen, was lacking considering the levels and duration of previous maintenance fertilization. There was little evidence at this stage to suggest that plant litter accumulated from previous years is decomposing and contributing significantly to the nutrient pool so important in nutrient cycling and which ensures a stable self-sustaining plant cover. The success of the attempt to introduce alfalfa into the plant cover as the legume replacement for the white clover, which has virtually disappeared from the cover, will be assessed in later years to determine legume contribution to a stable, self-sustaining plant cover in stressful, low-nutrient plant growth environments.

LIST OF REFERENCES

Russell, W.B. and S.K. Takyi. 1979. Cadomin Reclamation Research Project - First Year (1978) Results. Alberta Energy and Natural Resources. Edmonton. ENR Report No. 121.

Takyi, S.K. 1984. Role of Topsoil, Fertilizers and Companion Crops in 'Revegetation of Two' Severe Sites in the Alberta Foothills and Mountains. Alberta Energy and Natural Resources. Edmonton. ENR Report No. T/67.

Islam, M.R. and S.K. Takyi. 1984. Cadomin Reclamation Research Project Third, Fourth and Fifth-Year Results. Alberta Energy and Natural Resources. Edmonton. ENR Report No. T/56.

Takyi, S.K. and W.B. Russell. 1980. The Cadomin Reclamation Research Project - Second Year Results (1979). Alberta Energy and Natural Resources. Edmonton. ENR Report No. 155.

Ziemkiewicz, P.F. 1979. The Capacity of Reclamation Plant Communities to Supply Their Own Nutrients: When Does Maintenance Fertilization Become Unnecesary? In Proceedings: Canadian Land Reclamation Association, Fourth Annual Meeting. Regina, Saskatchewan.

REVEGETATION OF OIL & GAS DISTURBANCES, SEED MIXES, FERTILIZERS AND APPLICATION METHODS

P.F. ZIEMKIEWICZ

ABSTRACT

Revegetation contractors in the Oil and Gas Industry frequently encounter a different set of circumstances at each job site. Work sites tend to be numerous and small and site conditions can be severe enough to result in revegetation failure. Much of the revegetation work is done by field staff and because of the nature of the work timeliness is critical and exhaustive consultation and study is often impractical.

The following paper was developed to provide a methodology for field staff to quickly assess significant site conditions and taylor their revegetation treatments to meet site specific requirements.

Revegetation Objectives

Revegetation is the process of establishing vegetation on disturbed sites. It is a more limited process than reclamation in that it does not include materials handling, resloping and establishment of the desired end land use. For the purposes of this discussion we will assume that the materials have been handled and graded and that we are looking at a large patch of bare ground which is in need of plant cover.

In wildland revegetation the first objective is erosion control. Until the surface is stabilized attempts to impose higher value land uses (forestry, wildlife, recreation etc.) will fail. Reclamation surfaces are destabilized by three main factors: slope failures, water erosion and wind erosion. Slope failures are an engineering problem. The solution to water and wind erosion problems, however, are largely within the revegetation sphere.

While establishment of an erosion-controlling cover is of prime concern other factors should be considered. Revegetation in the oil and gas industry may face constraints due to fire hazard. Almost anything will burn if it gets hot enough. This certainly applies to vegetation, green or brown. The operator must judge whether the severity of

the hazard warrants 100% elimination of on-site fire. If it does then do not plant vegetation. However, proper vegetation management can make the difference between a tolerable, infrequent smolder and yearly conflagrations.

Weed Control is another revegetation objective in the oil and gas industry. Linear disturbances make excellent avenues for noxious weed invasion. This may cause profound concern among ranchers, farmers and the Department of Agriculture. Over large areas the cheapest way to exclude noxious weeds is to establish competing vegetation. Most weeds are opportunists and do not compete effectively against established, perennial vegetation.

Recreation/Wildlife/Livestock uses are inevitable if not always entirely desirable side affects of revegetation. Recreation increases fire and erosion risks and grazing pressure usually ranges from too much to way too much. The reason is simple; most of the plants available for reclamation are forage crops which the Europeans have obligingly bred for centuries to enhance their appeal to cattle and sheep. Even wild grazers, faced with their usual stringy, thorny and semi-poisonous diets will gratefully locate and demolish reclamation plants. Legumes are particularly attractive to wildlife and livestock because of their high nutrient content. In fact, excessive grazing may eliminate the legumes from a reclaimed area.

Revegetation Variables

In facing a revegetation problem one must meet the objectives with a rather limited inventory of treatments. These fall into three categories:

1) Species Selection

2) Fertilizer Management

3) Application Methods

1) **Species Selection**. There are 15 grasses and 8 legumes which are used extensively in North America for revegetation. These forage and turf species are about the only species commercially available for reclamation in Alberta which are proven performers.

All of these species have their strong and weak points. On a given site if you have a feel for the climatic and soil factors and the management requirements

it is fairly simple for an experienced individual to put together a successful seed mix. There is no substitute for experience when it comes to designing seed mixes. However, many situations arise where a seed mix must be specified in the absence of expert opinion. The following discussion is meant for such situations and will just about ensure a satisfactory seed mix for Alberta conditions.

Within our scope of discussion nine main factors will determine whether a species succeeds or fails. Along these parameters I have taken the liberty of ranking the 15 grass and 8 legume species on scales of 1-10 (Table 1) to indicate their relative suitability. Use of the Table is simple and involves the following steps:

1. Identify critical site parameters

2. Add up the rating values for each species

3. Divide by the number of parameters used

4. Select the three highest ranked grasses and two highest ranked legumes

Table 1. Species, Revegetation Parameters and Ratings

	REVEGETATION PARAMETERS								
	1	2	3	4	5	6	7	8	9
Grasses	Drought Tolerance	Nutrient Deficiency Tolerance	Grazing Resistance	Fire Resistance	High Elevation Tolerance	Flooding Tolerance	Acid Tolerance	Salt Tolerance	Erosion Control
1. Canada Bluegrass	9	1	10	10	8	1	8	8	9
2. Crested Wheatgrass	10	1	10	9	2	1	1	9	8
3. Intermediate Wheatgrass	8	1	9	1	4	1	1	7	8
4. Meadow Foxtail	5	1	7	2	10	9	8	1	8
5. Orchardgrass	4	1	2	2	9	1	6	1	8
6. Perennial Ryegrass	5	1	6	5	2	1	5	1	8
7. Red Fescue	8	1	8	5	10	1	10	3	10
8. Red Top	1	1	5	5	10	8	9	1	8
9. Reed Canarygrass	3	1	7	1	1	10	5	8	8
10. Sheep Fescue	8	1	5	8	10	1	6	1	5
11. Slender Wheatgrass	8	1	7	2	6	1	4	7	8
12. Smooth Brome	8	1	7	1	5	1	10	4	9
13. Tall Wheatgrass	8	1	10	1	2	7	1	10	8
14. Timothy	5	1	9	1	10	3	6	1	4
15. Western Wheatgrass	9	1	8	2	2	1	1	10	8
Legumes									
1. Alfalfa	8	10	4	5	5	1	1	8	8
2. Alsike Clover	5	10	6	8	10	1	7	1	8
3. Birdsfoot Trefoil	5	10	4	7	3	1	6	1	5
4. Cicer Milkvetch 1)	7	10	7	6	7	1	2	6	3
5. Red Clover	1	10	3	8	3	1	3	1	8
6. Sainfoin	8	10	4	5	3	1	1	7	5
7. Sweetclover 2)	9	10	10	1	1	1	1	10	1
8. White Clover	1	10	6	8	8	2	3	1	8

1)= Use only Scarified Seed

2)= Though it rates high in some categories Sweetclover is not recommended due to its poor persistence.

Table 2 shows examples of this procedure for nine site descriptions. The results generally match my personal prejudices. (The Reader should take note that these ratings devolve from my accumulated opinions of plants and they should not be mistaken for unassailable truth). Where there is a tie score go with your own prejudices or whichever seed is cheapest. The critical part of this system is identification of the site parameters. These are simple enough that an accurate assessment of critical parameters will be quick and easy.

1. **Drought Tolerance**. If the soil is sandy or gravelly then you will probably have a droughty site. Also South facing slopes and most sites in Southeastern Alberta can be assumed to be dry. If in doubt include drought tolerance as a factor. The drought-hardy plants will do well in moist sites but non-drought-hardy plants will die on a dry site.

2. **Nutrient Deficiency Tolerance**. If you do not plan to replace topsoil or fertilize a site regularly then this factor should be included, mainly as a reminder to keep up the legume content of the mixes.

3. **Grazing Resistance**. Any wildland or pasture planting will get some wildlife or domestic grazing. If grazing pressure is likely to be heavy non-resistant species may be grazed out. Addition of this factor will keep grazing resistant species in the mix and provide a measure of erosion control even on heavily grazed spots.

4. **Fire Resistance**. Self-explanatory.

5. **High-Elevation Tolerance**. Many agronomic species will not persist at high elevations (above roughly 6,000 ft. in the South and 5,500 ft. in the North).

6. **Flooding Tolerance**. Include if ponding is likely to be a problem, even if sporadic.

7. **Acid Tolerance**. Strongly acid soils are rarely a problem in Alberta but they may crop up around sulfur stockpiles, acid drilling mud spills and in some of the black shales in the mountains (Fernie formation). Include only if strong acidity is going to be a problem (pH less than 5.0).

8. **Salt Tolerance**. Include if you expect salt spills or naturally saline soil.

9. **Erosion Control**. Some species develop erosion control more quickly than others. On erodible sites (slopes, sandy soils) this factor is very significant.

Table 2. Examples of Seed Mixes Predicted for Various Site Types

	SITE DESCRIPTIONS								
	A	B	C	D	E	F	G	H	I
Grasses	Foothills, Sandy Soil, Slope, Fire Hazard #1, 2, 3, 4 and 9	Foothills, Heavy Soil, Slope, Fire Hazard #2, 3, 4 and 9	Alpine, Heavy Soil, Slope, Poor Drainage #2, 3, 5, 6 and 9	Plains, Heavy Soil, Saline, Fire Hazard #1, 2, 3, 4 and 8	Peace Region, Heavy Soil, Saline #2, 3 and 8	Foothills, Acid Soil, Fire Hazard #2, 3, 4 and 7	Alpine, Acid Soil, #2, 3, 4, 5, and 7	Plains, Gravelly, Acid Soil, #1, 2, 3 and 7	Alpine, Gravelly Soil, Slope #1, 2, 3, 5 and 9
1. Canada Bluegrass	*78	*75	58	*76	63	*72	*74	*70	*74
2. Crested Wheatgrass	*76	*70	46	*78	*66	*52	46	55	62
3. Intermediate Wheatgrass	54	48	46	52	57	30	32	48	60
4. Meadow Foxtail	42	39	*62	28	21	39	52	46	*62
5. Orchardgrass	34	32	42	20	13	35	40	32	48
6. Perennial Ryegrass	50	50	36	36	27	42	38	42	44
7. Red Fescue	*61	*55	57	47	33	*55	*65	*63	*74
8. Red Top	40	48	*64	26	23	50	*60	40	50
9. Reed Canarygrass	40	42	54	40	53	35	30	40	40
10. Sheep Fescue	52	47	44	46	23	50	60	50	58
11. Slender Wheatgrass	52	45	46	50	50	35	40	50	60
12. Smooth Brome	52	45	46	42	40	47	48	*65	60
13. Tall Wheatgrass	54	50	56	58	*70	32	30	50	58
14. Timothy	40	38	54	34	37	42	54	52	58
15. Western Wheatgrass	56	48	40	*60	*63	30	28	47	56
Legumes									
1. Alfalfa	*70	67	56	*70	*73	50	50	57	*70
2. Alsike Clover	*74	*80	*70	60	57	*77	*82	*70	*78
3. Birdsfoot Trefoil	52	65	46	54	50	*67	60	62	54
4. Cicer Milkvetch 1)	66	65	56	*72	*77	62	64	*62	68
5. Red Clover	60	72	50	46	47	60	54	40	50
6. Sainfoin	64	60	46	68	70	50	46	57	60
7. Sweetclover 2)	62	55	46	80	100	55	46	75	62
8. White Clover	66	*80	*68	52	57	67	*70	50	66

* = Recommended Seed Mix
1)= Use only Scarified Seed
2)= Though it rates high in some categories Sweetclover is not recommended due to its poor persistence.

2) **Fertilizer Management**. Topsoil is the best fertilizer. However if it is not available proper fertilizer management can be as significant as species selection in determining your final vegetation cover. Fertilizers are marketed according to their proportion of the three main nutrients: nitrogen, phosphorus and potassium expressed as % N-%P_2O_5-%K_2O. So urea is 45-0-0 and monoammonium phosphate is 11-46-0. Almost all revegetation sites need fertilizer. The secret lies in determining what kind (grade) and how much (rate). In revegetation it is safe to assume that nitrogen and phosphorus are in short supply. If you are the cautious type you will want to use an N,P mixed fertilizer. If you are prone to take chances you can cut fertilizer costs dramatically by using a straight nitrogen fertilizer (e.g., ammonium nitrate, urea, ammonium sulfate). Soil potassium is usually in adequate supply and can be deleted from further consideration.

The first fertilizer addition should provide 50-75 lbs/ac (kg/ha) of nitrogen. If the plant cover starts yellowing and dying off by the middle of the first two growing seasons then a second or third application of ½ the original rate should be made the next Spring. Thereafter one should resist the temptation to fertilize unless erosion poses an immediate hazard. Excessive fertilization will only generate a fire hazard in thick, dry vegetation and create a feedlot for the local grazers. Also, overfertilization allows the grass to outcompete the legumes. It is much better to allow the legumes to develop and do what they do best: turn atmospheric nitrogen into useable nitrate and ammonium.

3) **Application Methods**. The means of applying seed and fertilizer may also significantly affect revegetation success. In Alberta seeding and fertilizing should be done in Spring/early Summer if access is available. In the mountains early season access is usually limited. If late access would mean mid-Summer planting it is usually best to seed in Fall and fertilize in Spring. Do not apply fertilizer in the Fall. It will be gone by the time the seedlings need it.

Unless applied seed is covered by soil or mulch it will only serve as bird feed. Sometimes seeding on extremely rough or recently worked soil will produce an acceptable catch. However, to be sure either cultivate or harrow after seeding. Seed drills and Brillion-type seeders accomplish seeding and incorporation in one step but both require a smooth and nearly rock-free seed bed. They are also almost impossible to use on steep slopes. Their use, however, should not be ruled out on flat or subdued slopes

and particularly on sandy sites or wherever topsoil has been applied. Proper use of a seeder or drill (which most farmers have) gives the best chance of success with the minimum amount of seed and machine time.

When using any of the broadcast methods (via aerial, tractor or hand-carried cyclone) 50 lbs/ac (Kg/ha) of seed is the standard recommendation. When a seed drill is used the seeding rate may be halved. These rates are high but are meant to cover a wide range of seed bed conditions. If you do not get good establishment with these rates then the problem lies elsewhere (poor seed bed/incorporation, soil toxicities, wrong seed mix or droughty conditions).

Seed and fertilizer should be applied together in the Spring and incorporated (harrowed) within a few days, the sooner the better. For isolated, small sites (less than 30 ac) perhaps the most effective method is to send in a five man crew with cyclone seeders just before the dozer leaves the site. A good crew can finish seeding and fertilizing a 30 ac site in about 4-5 hours and the dozer then drags a harrow around on its last pass.

For long linear disturbances, numerous small sites within a radius of less than 2 miles or very large sites (greater than 60 ac) aerial (helicopter) application of seed and fertilizer is best. Site preparation is critical. Where there has been compaction due to vehicle traffic (roads, pipeline rights-of-way) ripping should precede seeding and again harrowing should be the final step.

Hydroseeding is often the only way to apply seed, fertilizer and sometimes mulch to steep slopes and it is almost always the most expensive way. It is ideal for seeding active road cast banks, steep slopes or where erosion control is an immediate requirement. In such cases immediate erosion control may be achieved by using a hydro mulch, usually in conjunction with a soil binder. The mulch is usually applied at between 1000 to 3000 lbs/ac increasing with greater erosion hazard. Wood fiber mulches seem to give the best results. Also many chemical binders are on the market. These are applied at rates of 40 to 100 lbs/ac and help bind the mulch to the soil surface and improve soil structure.

Some binders are effective and some are a useless expense. Research in California [1)] indicates that heavier rates of wood fiber mulch are as effective as some binders in reducing erosion hazard. However, at high rates of application fiber mulches may inhibit seedling germination

and emergence. Work on logging roads on Vancouver Island [2] indicates that hydroseeding alone had as much effect in controlling erosion as hydroseeding plus hydromulching and binders. Hydromulching should only be used where immediate erosion is a concern and seedling establishment is expected to be slow. Keep in mind that soil is the best mulch and if possible stick with broadcasting and harrowing.

1) Kay, B.L. 1977 Hydroseeding and Erosion Control Chemicals. In Thames, J.L. (Ed) Recl. & use of Disturbed Land in the Southwest Univ. of Ariz. Press. Tuscon, A.R. 361p.

2) Carr, W.W. 1977 Hydroseeding of Forest Road Slopes for Erosion Control & Resource Protection. M.Sc. Thesis Univ. of B.C. Faculty of Forestry. 55p.

SUMMARY

1) **SEED MIXES** - There are about 15 grasses and legumes to choose from. The number of possible combinations is staggering. Fortunately, for the sake of simplicity, many of these species are mediocre performers. If you had a choice of only five species to use across all oil and gas disturbances in Alberta you would do reasonably well using Red Fescue, Crested Wheatgrass, Canada Bluegrass, Alfalfa and Alsike Clover.

2) **FERTILIZER MANAGEMENT** - The best way to eliminate this as a concern is to respread topsoil. Otherwise in the initial year use about 50-75 lbs/ac of nitrogen and as much phosphorus. If further fertilization is needed in succeeding years use half as much. Avoid more than two years of maintenance fertilization.

3) **APPLICATION METHODS** - Several methods are available. Use one which incorporates the seed into the soil (Broadcast and Harrow, Seed Drilling, Brillion Seeder). If steep slopes make this impossible hydroseeding should be considered. However hydroseeding is very expensive.

EXAMPLE

(Site Description 'A' Table 2)

Species		Drought	Nutrient	Grazing	Fire	Erosion Control	
Canada bluegrass	Parameter	1	2	3	4	9	**TOTAL**
	Score	9	+ 1	+ 10	+ 10	+ 9 =	39 =.78=78%
	Possible	10	+ 10	+ 10	+ 10	+ 10=	50
Redtop	Parameter	1	2	3	4	9	
	Score	1	+ 1	+ 5	+ 5	+ 8	20 =.40=40%
	Possible	10	+ 10	+ 10	+ 10	+ 10	50

Formula for Calculating Scores

$$\text{Species Score} = \frac{\sum_{i=1}^{n} R_s}{10n} \times 100$$

Where: n = Number of Parameters
R = Rating
s = Species
$\sum$ = Summation

RECLAMATION RESEARCH AT NO. 8 AND NO. 9 MINES GRANDE CACHE, ALBERTA

T.M. Macyk
Soils Department
Alberta Research Council
Edmonton, Alberta

and

B.A. Skirrow
Smoky River Coal Ltd.
Grande Cache, Alberta

ABSTRACT

The Soils Department of the Alberta Research Council has been conducting a reclamation research program in the Grande Cache area on behalf of Smoky River Coal Ltd. since May, 1972. The main objective of the study is to determine methods of establishing long-term vegetative cover that is in harmony with adjacent, undisturbed areas. The unmined soils and the soils reconstructed after mining were characterized. Plot studies to determine the suitability and adaptibility of various agronomic and native grasses and legumes, as well as fertilization trials, were established. Conifer seedlings and cuttings of deciduous species were planted in the reconstructed soil areas following establishment of a grass and legume cover. Long term results indicate that agronomic grasses and legumes will thrive and reproduce and that native grasses and legumes will invade the revegetated areas. Trees and shrubs will become established in areas initially seeded to a grass and legume cover.

INTRODUCTION

The Alberta Research Council, Soils Department has been conducting a reclamation research program in the Grande Cache area on behalf of, and funded by, Smoky River Coal (formerly McIntyre Mines Ltd.) since May, 1972. At that time, reclamation research was truly in its infancy in Alberta and techniques developed elsewhere, primarily in the United States, were not applicable to the problem at hand. This paper provides a summary of some of the aspects of this on-going project. Details relating to various aspects of the study are documented in the reports prepared annually (see reference list).

Setting

The operations of Smoky River Coal Ltd. are located approximately 13 km north of Grande Cache in the Rocky Mountain Foothills. The two major surface mining operations are the No. 8 and No. 9 Mine areas located adjacent to the Smoky River and Sheep Creek respectively. Elevations range from 1600 to 1800 m and the topography is steeply sloping. Climate is considered to be one of the major limiting factors to revegetation success. Frost and/or snow can and do occur in any month of the year and wind is a common phenomenon.

Objectives

The original objectives of the project were defined as follows. New ones were added as additional needs were identified.

1) to determine the properties of the undisturbed and reconstructed soils in the mine areas and evaluate their suitability for reclamation purposes;

2) to determine, by field testing, suitable species of grasses and legumes for establishing a protective vegetative cover on the reclaimed areas to minimize erosion;

3) to determine, by field and laboratory testing, the nutrient requirements for maintaining a viable vegetative cover; and

4) to determine methods of establishing a long-term vegetative cover that is in harmony with the adjacent, undisturbed areas.

MATERIALS AND METHODS

Coal production from the No. 8 Mine commenced in June, 1971. The research program which placed emphasis on soils and vegetation concerns began in May of 1972.

Pre-Mining Soils

A soil survey of that portion of the No. 8 Mine area that had not yet been disturbed by mining indicated that the soils were dominantly Luvisolic and Brunisolic (CSSC 1978) with the depth of salvageable material overlying

bedrock ranging from 10 cm to 1 m. Table 1 provides means and standard deviations for pH, particle size and available nutrients for samples collected at eight sites.

Table 1. Analytical Data for Soils in the Unmined Setting

			Particle Size (%)						Available Nutrients (Kg/ha)					
Depth	pH		Sand		Silt		Clay		Nitrogen		Phosphorus		Potassium	
(cm)	Mean	S.D.*	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
0-15	5.8	1.2	31	9	50	7	19	5	0.8	0.7	32	27	186	134
15-30	5.6	0.5	30	10	52	11	18	6	0.6	0.7	13	13	185	135
30-45	6.3	1.0	28	16	55	16	17	9	0.6	0.7	13	12	123	41
45-60	6.5	1.2	29	18	52	17	20	4	0.5	0.5	8	7	103	28

*S.D. - Standard Deviation

The data indicate that the unmined soils are moderately to slightly acid, medium textured and have low levels of available plant nutrients, especially nitrogen and phosphorus.

Materials Handling Procedures

Soil salvage is an integral part of the materials handling program associated with the overall mining operation. Following the removal of merchantable timber, the soil overlying consolidated bedrock is removed in one lift in a manner such that a minimum amount of coarse fragments are incorporated. The soil materials are stockpiled for future use. Because the surface or organo-mineral horizons are minimal or nonexistent and the sola are quite variable in thickness, segregation or selective handling of soil materials is not considered.

Soil material is replaced on the spoil surface by scrapers or truck/caterpillar operations following the removal of overburden and coal and subsequent backfilling and grading. Scrapers tend to allow for a more uniform depth of soil replacement but they are limited by slope angle and they cause more severe compaction under moist conditions. Caterpillars are not as versatile as scrapers, however their tracks provide excellent seed germination sites.

Reconstructed (Post-Mining) Soils

The reconstructed soils that are developed do not duplicate the soils that existed prior to disturbance. The physical properties of the soils are the ones most drastically altered by the mining process.

Table 2 provides analytical data for the surface (0-15 cm) material of the reconstructed soils at three of the experimental sites established in the first year of the project. Additional information pertinent to reconstructed soil characteristics is contained in the annual reports.

Table 2. Analytical Data for the Surface Material (0-15 cm) of Reconstructed Soils

			Particle Size (%)						Available Nutrients (Kg/ha)					
	pH		Sand		Silt		Clay		Nitrogen		Phosphorus		Potassium	
Area	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
I	6.6	0.8	36	6	44	7	20	6	0.8	0.5	13	6	124	71
II	7.0	1.1	40	11	45	8	15	5	0.8	0.5	6	5	107	42
III	8.2	0.4	not determined						0.5	0.3	3	3	144	12

The data indicate that reconstructed soils are generally coarser textured, higher in pH and lower in available nutrients than unmined soils. These soils have some limitations, however, with proper management they are invaluable in achieving reclamation success.

Vegetation Establishment

In the spring of 1972, three plot areas, the first of many to be utilized during the project term, were established involving 60 individual 6 x 9 m plots to determine the suitability of numerous agronomic grasses and legumes (Table 3). These grasses and legumes were planted singly and/or in mixtures. Complete details are provided in the annual reports (Macyk 1972, 1973, 1974, 1975, 1976, 1979).

Initially, the use of grasses and legumes was queried because the region is characterized by forest cover. The grasses and legumes were utilized to provide an initial quick cover to minimize erosion.

The plots were located on slopes ranging from 0 to 40 degrees. Fertilizer trials were included to determine the most appropriate fertilizer types and analyses to be used, as well as timing and rate of application.

A concern relative to utilization of native species was addressed early in the study. It had been suggested that native species be utilized because animals prefer them, that less maintenance is required after establishment and that natives are more aesthetically pleasing. Realistically, however, in 1972 there was very little "native" seed available. Consequently, seed from loco-weed (Oxytropis spp.), Alpine hedysarum (Hedysarum alpinum), lupine (Lupinus spp.) and Hairy wildrye (Elymus innovatus) was collected in the undisturbed portions of the mine area and subsequently cleaned and planted.

Table 3. Agronomic Grasses and Legumes Utilized for Revegetation

Legumes
Alfalfa - Beaver, Chimo, Drylander, Rambler, Roamer
Alsike Clover
Birdsfoot Trefoil - Leo
Cicer Milk Vetch
Sweet Clover
White Clover
Vetch - Spring, Crown
Grasses
Bromegrass - Carlton, Magna, Polar
Creeping Foxtail
Creeping Red Fescue - Arctared, Boreal, Erica
Crested Wheatgrass - Fairway, Nordan
Durar Hard Fescue
Intermediate Wheatgrass
Kentucky Bluegrass
Meadow Foxtail
Nugget Bluegrass
Perennial Ryegrass
Pubescent Wheatgrass
Redtop
Rough Fescue
Russian Wildrye (Sawki)
Slender Wheatgrass
Streambank Wheatgrass
Tall Wheatgrass
Timothy

The native species issue was also approached from the standpoint of introducing trees and shrubs relative to meeting the objective of establishing a long term cover that is in harmony with the surrounding area. A major problem was encountered in that seedlings suitable for planting above an elevation of 1100 m were unavailable. Consequently, a cone collection program was undertaken and greenhouse space acquired to rear lodgepole pine (*Pinus contorta* var. *latifolia*), engelmann spruce (*Picea engelmannii*) and white spruce (*Picea glauca*). Different sizes and types of containers were utilized to determine those most suitable for use in reconstructed soils and to get an appreciation of the relative costs associated with seedling production.

Cuttings of willow (*Salix* spp.), balsam poplar (*Populus balsamifera*) and root cuttings of aspen (*Populus tremuloides*) were rooted in the greenhouse. Direct planting methods were also utilized for the cuttings of willow. Most of the materials were planted within areas having an established grass and/or grass/legume cover.

During the first five years of the study, approximately 16,000 conifer seedlings and 2000 shrub and deciduous tree cuttings were planted in areas that had an established cover of agronomic grasses and legumes.

RESULTS AND DISCUSSION

Suitability of Agronomic Grasses and Legumes

Most of the agronomics that were planted initially survived and continue to thrive. Many of the species produced and dropped viable seed. There was some concern at the outset that legumes, and in particular alfalfa, would not adapt or survive at the elevations involved in this study.

Time and annual monitoring of growth resulted in the development of an appreciation of species suitability (desirability), stand composition and fertilizer requirement. For example, with time and the withholding of fertilizers, alfalfa increased its share of the ground cover while the grasses, which tended to comprise a major portion of the initial cover in a mixed stand, declined in vigor. A number of recommended seed mixtures and seeding rates appropriate for different slope aspects (moisture regimes) were developed and are documented in the annual reports prepared (Macyk 1975, 1976, 1977). In terms of the most suitable time of year for planting, it was determined that spring seeding is superior to fall seeding for a number of reasons. The major reason for spring planting is that legumes, which should be included in the cover established, perform much better when seeded in the spring.

To summarize, one might suggest that legumes such as alfalfa and clover along with the fescues, wheatgrasses, and wildryes are the most appropriate for revegetation use. Bromegrass and timothy provide good initial cover but tend to be highly competitive in mixtures and have relatively high nutrient requirements.

Fertilizer Requirements

As indicated previously, the available nutrient levels of the undisturbed and reconstructed soils was quite low. The grasses and legumes showed a marked response to the application of fertilizers to the extent that fertilized plots produced 10 to 20 times more dry matter than the unfertilized plots.

In response to the initial results obtained, some concerns were raised. There arose the concern that large applications of fertilizer would be required annually to maintain the established cover. Furthermore, the established cover was relatively dense which it was suggested, would preclude invasion by natives and that resultant dead plant material would create a fire hazard in spring. The dead plant material probably does create a fire hazard but it is also useful from the standpoint of improving the organic matter status of the reconstructed soil. Fertilizer requirements relative to timing, type and rate were developed on the basis of observations made during the study. A summary relative to timing follows:

1) fertilizers should be applied at the time of seeding (year 1) and the following year (year 2);

2) for areas seeded to mixtures comprised of grass only, refertilization should take place in year 3 and then every three years thereafter;

3) for areas where legumes such as alfalfa are included in the mixture, the vegetation cover can be left for five years and perhaps longer without refertilization.

Native Species Trials

Results indicated that the seed of some of the native grasses and legumes collected had relatively low germination rates. For example, the germination rate for loco-weed was 70 percent, whereas that of alpine hedysarum was 15 percent. It was observed that establishment of a viable erosion control cover utilizing natives only, took at least two years longer than it did when agronomics were used. Despite some of the limitations associated with utilizing natives, the species used in this study are considered appropriate for large scale use. A major concern relates to the acquisition of an adequate seed supply.

Relatively good success was achieved in terms of tree and shrub establishment. It was demonstrated that trees and shrubs will thrive in areas initially seeded to grasses and legumes. This practice was questioned initially because of an anticipated competition for moisture. It became apparent that the protection afforded the seedlings by the grass and legume cover, especially in holding snow in the winter, far outweighed the negative aspects of moisture competition during the growing season.

Furthermore, it was noted that seedlings growing in association with alfalfa appeared more healthy and vigorous than those growing in association with grasses.

The following summary represents an assessment of results five years after the initial planting of trees and shrubs.

1) engelmann spruce survival rate - 65%

2) lodgepole pine survival rate - 50%

3) rooted willow and balsam cutting survival rate - 65%

4) direct planted willow cutting survival rate - 40%

5) container grown conifer seedlings are superior to bare root stock in terms of survival and growth rate

6) larger size containers promoted higher survival rates.

Some problems were encountered relative to seedling mortality. Upon investigation of some of the seedlings that had expired, it became apparent that the upper root mass surrounded by the peat from the original container was exposed at the soil surface. This exposure is likely the result of frost heaving.

Recently, emphasis was placed on assessing some of the characteristics of trees planted in the reclaimed area and relating this to trees present in the adjacent forest. Trees selected for examination or comparison were chosen on the basis of obtaining similar species and sizes from both the natural and reclaimed areas. Trees were excavated to allow for examination of rooting habit and depth. Stem diameter at the base and age of each individual tree were determined.

Roots were concentrated in the upper 30 cm of the soil with only minor rooting below 50 cm for both spruce and pine within the reclaimed and undisturbed areas. Rooting habit or pattern was quite similar for trees excavated from the undisturbed and reclaimed areas.

The effect of existing grass cover on tree development was assessed. The trees growing in a relatively dense grass cover exhibited relatively sparse rooting systems. The trees growing in a less dense cover had considerably more well developed rooting systems.

The age-growth relationships for spruce and pine were examined to some extent. The values presented in Table 4 are based on a mean of 10 trees for each species and location.

Table 4. Age and Growth Data for Conifers in the No. 8 Mine Area

Spruce		
Location	Diameter (cm) at Base	Age
Reclaimed	1.2	9
Natural	1.1	22
Pine		
Location	Diameter (cm) at Base	Age
Reclaimed	2.6	11
Natural	2.5	30

The data indicate that the growth rate for trees in the reclaimed area is considerably greater than that of trees growing in the natural forest. These results might be explained by the fact that the trees in the reclaimed setting may have benefitted to an extent from the fertilizers applied to the accompanying grass cover. Furthermore, the trees in the reclaimed area likely receive more direct sunlight than the trees in the natural forest setting. However, it should be pointed out that the trees in the reclaimed area are more exposed to climatic extremes such as wind.

Encroachment by Natives

Field observations indicate that encroachment by natives into the disturbed areas will occur with time. Various mosses, lupine, loco-weed, alpine hedysarum and Indian paintbrush (Castillejia tularensis) are naturally invading the areas initially seeded to agronomics. Willow, alder and balsam poplar are the dominant tree invaders, however, conifers such as spruce and pine have been observed, especially near the margins of the disturbed area.

The encroachment by natives is the result of seed spreading from adjacent undisturbed areas and/or the result of incorporation of seed and vegetative material during soil salvage operations and the resultant germination of seed or sprouting of vegetative material following soil replacement.

Wildlife Utilization of Reclaimed Areas

During the initial stages of the study it was suggested that most wildlife species would not utilize reclaimed areas especially those where agronomic grasses and legumes were utilized. Bighorn sheep initially inhabited the experimental areas only in spring because the plots greened up earlier than their native range. Presently, they stay within the reclaimed area throughout the growing season, selectively grazing particular species such as alpine bluegrass, creeping foxtail, hard fescue and to some extent the tender shoots of alfalfa.

CONCLUSIONS

Reclamation efforts in the Foothills/Mountains Region can be successful provided that appropriate procedures are adopted. Soil management and the selection of suitable agronomic and native species aided by natural processes will result in the establishment of diverse plant communities and allow for different land use options.

REFERENCES

Canada Soil Survey Committee, Subcommittee on Soil Classification, 1978. The Canadian System of Soil Classification, Canada Department of Agriculture Publication 1646. Supply and Services Canada, Ottawa, Ontario, 164 pp.

Macyk, T.M. and Widtman, Z.W., 1983. Progress report, surface mine reclamation project, No. 8 and No. 9 Mines, Grande Cache, Alberta. Alberta Research Council, Soils Department Report, 28 pp.

Macyk, T.M., 1982. Progress report, surface mine reclamation project, No. 8 Mine, Grande Cache, Alberta. Alberta Research Council, Soils Department Report, 18 pp.

Macyk, T.M., 1982. Progress report, surface mine reclamation project, No. 9 Mine, Grande Cache, Alberta. Alberta Research Council, Soils Department Report, 12 pp.

Macyk, T.M., 1981. Progress report, surface mine reclamation project, No. 8 Mine, Grande Cache, Alberta. Alberta Research Council, Soils Department Report, 21 pp.

Macyk, T.M., 1981. Progress report, surface mine reclamation project, No. 9 Mine, Grande Cache, Alberta. Alberta Research Council, Soils Department Report, 14 pp.

Macyk, T.M., 1980. Progress report, surface mine reclamation project, No. 8 Mine, Grande Cache, Alberta. Alberta Research Council, Soils Department Report, 26 pp.

Macyk, T.M., 1980. Progress report, surface mine reclamation project, No. 9 Mine, Grande Cache, Alberta. Alberta Research Council, Soils Department Report, 17 pp.

Macyk, T.M., 1979. Progress report, surface mine reclamation project, No. 8 Mine, Grande Cache, Alberta. Alberta Research Council, Soils Department Report, 21 pp.

Macyk, T.M., 1979. Progress report, surface mine reclamation project, No. 9 Mine, Grande Cache, Alberta. Alberta Research Council, Soils Division Report, 31 pp.

Macyk, T.M., 1978. Progress report, surface mine reclamation project, No. 8 Mine, Grande Cache, Alberta. Alberta Research Council, Soils Division Report, 36 pp.

Macyk, T.M., 1978. Progress report, surface mine reclamation project, No. 9 Mine, Grande Cache, Alberta. Alberta Research Council, Soils Division Report, 22 pp.

Macyk, T.M., 1977. Progress report, strip mine reclamation project, No. 8 Mine, Grande Cache, Alberta. Alberta Research Council, Soils Division Report, 41 pp.

Macyk, T.M., 1977. Progress report, strip mine reclamation project, No. 9 Mine, Grande Cache, Alberta. Alberta Research Council, Soils Division Report, 20 pp.

Macyk, T.M., 1976. Progress report, strip mine reclamation project, No. 8 Mine, Grande Cache, Alberta. AIP Report M-76-11, 43 pp.

Macyk, T.M., 1976. Progress report, strip mine reclamation project, No. 9 Mine, Grande Cache, Alberta. AIP Report M-76-23, 18 pp.

Macyk, T.M., 1975. Progress report, strip mine reclamation project, No. 8 Mine, Grande Cache, Alberta. AIP Report M-75-9, 37 pp.

Macyk, T.M., 1974. Progress report, strip mine reclamation project, No. 8 Mine, Grande Cache, Alberta. AIP Report M-74-16, 39 pp.

Macyk, T.M., 1973. Progress report, strip mine reclamation project, No. 8 Mine, Grande Cache, Alberta. AIP Report M-73-14, 35 pp.

Macyk, T.M., 1972. Interim report, strip mine reclamation project, No. 8 Mine, Grande Cache, Alberta, 20 pp.

PLANT COVER ESTABLISHMENT METHODS ON A SEVERE ROCKY MOUNTAIN FOOTHILLS SITE [1]

S.K. Takyi

Alberta Forest Service

Department of Energy and Natural Resources

Edmonton

INTRODUCTION

The major causes of drastic land disturbances in the alpine and subalpine areas of Alberta are surface mining, oil and gas well development, pipeline construction and the access infrastructures which service installations and bring the resources to markets. Some forestry operations also involve drastic land disturbances. With continuing demands for natural resources, activities leading to land disturbances will continue. The disturbance rate may be accelerated in the next few decades. Although there have been good examples of successful reclamation in the subalpine and alpine areas, there are several examples of failure in very critical areas, which, if they had received the appropriate

---

[1]This paper has been published as Energy and Natural Resources Technical Report Number: T/66.

reclamation treatments, could have had greater chance of reclamation success. High elevation areas play a vital role in our watershed and recreational resources, which should be given the same importance accorded wildlife and forestry resources in these areas.

Critical areas which are difficult to stabilize and revegetate in the high elevation zones in Alberta include steep slopes and road cuts and spoil piles, disturbed wind-swept areas, approaches to stream and creek crossings, and areas of poor soil materials requiring special treatments. In many cases in these high-elevation disturbances, the establishment of a plant cover can be achieved with the same revegetation principles and techniques employed in ecosystems with a much less harsh plant-growth environment. The role played by the less than hospitable plant-growth environment in the high-elevation areas cannot be over-emphasized. For what might seem to be similar site conditions on disturbed sites in a low elevation ecosystem and a high elevation ecosystem, reclamation problems could be magnified severalfold in the latter. Because of the harsh environment in the high elevation sites, these critical areas pose even greater problems and should therefore be given greater attention in terms of employing more reliable reclamation techniques. Never has the need for the development and implementation of suitable reclamation techniques for critical problem sites in disturbed high-elevation areas become more apparent than now, because of resource-extraction development which may be forthcoming in the next few decades. It means we should acquire the technology now to be able to restore land-surface stability, aesthetic compatibility and even productivity to high-elevation disturbances once we have removed the needed resources.

For such high-elevation environments, successful revegetation can most often be ensured if the physical environment is modified to meet as closely as possible the growth requirement of the selected plant species, native or introduced. Once the physical environment has been modified, the most critical problem is the adaptability of the selected species to the harsh climate. As indicated earlier, there has been considerable industrial activity in the high-elevation areas; unfortunately, reclamation of the critical areas has not always been successful primarily because the development and the implementation of suitable techniques have not kept pace with industrial activity. Observations of the situation confirm that specific reclamation techniques should be employed to handle site specific problems. For some time now there has been interest in Alberta in undertaking research into revegetation of land disturbances, primarily mining disturbances, to enhance reclamation success. The two experiments I will be discussing were started in 1979 and 1980 in an effort to find solutions to some revegetation problems, especially in the harsh and critical sites which have been difficult to revegetate.

The objectives of the studies were (a) to assess plant cover establishment success employing different methods of seeding a native grass seed mix on a very coarse and pervious mine overburden, (b) to assess the effect of seeding methods on growth following cover establishment, and (c) to evaluate the use of erosion-control materials and surface manipulation (ridging) as methods for establishing plant cover on a harsh site. I also sought to estimate the magnitude of erosion in relative terms. In planning these experiments I intended that the

methods be practical so the results could be applied to operational reclamation situations. As plant cover is recognized as the important component for determining adequate reclamation of disturbed land, especially in erosion problem situations, its successful establishment was an important objective of the experiments.

STUDY SITE

The two experiments are located on a coal mine abandoned in 1952 near the hamlet of Cadomin, on the Nikanassin Range. There are three operating surface mines and two others being planned within a 40 km radius of this abandoned mine. The elevation of the site is approximately 1 675 m ASL, just below treeline. Treeline in this area is at about 1 980 m ASL, but because of the disturbed and exposed nature of the site brought about by mining, environmental conditions strictly favour subalpine and alpine. Vegetation on the disturbances is very sparse and consists of isolated plants in open communities. The sites lacked any vegetation at the time of the establishment of the experiments. Mining at the site predated the requirement of environmental impact assessment and the current practices of soil stockpiling and selective overburden handling. The current site conditions attest to the lack of environmental planning.

One experiment (methods of erosion control) is located on a west-facing slope of a waste pile consisting of an admixture of sandstone, siltstone, shale overburden and coal fragments. The second experiment (establishment methods of native grasses) is located on a flat-top pile

consisting of much larger fragments of the same materials, but it contains no coal. At both experimental sites there is normally hardly any snow accumulation in the winter because of the high winds. The chinook wind common to the area rapidly removes any snow which remains on the sites. Because the chinook wind is so warm and dry the melted snow is vaporized in the winter and early spring and little of it benefits the sites, except for that which falls in late spring (early June). These two very harsh sites failed to regenerate naturally over the 30 years following mine abandonment and for this reason were selected for the experiments.

REVEGETATION METHODS

A. Methods of Erosion Control for Cover Establishment

The experiment was laid out in a randomized block design with four replications of five treatments each in early June, 1979. Treatments consisted of the use of three erosion-control materials, construction of ridges spaced at one-metre intervals across the slope, and a control. The three materials, jute net (Ludlow Soil Saver, Type #48 - heavy mesh), excelsior blanket (AMXCO "Curlex"), and "hold/gro" (the standard seeding type for slopes, ditches, etc.), were applied according to manufacturer specifications. The plots were laid out and ridges constructed where required. Seeding at a rate of 60 kg/ha was carried out by broadcasting, and followed by hand broadcast of fertilizer (600 kg/ha of 10:30:10 - 60 kg N : 78 kg P : 50 kg K/ha). Both fertilizer and seed were raked into all the plots, to be followed by the application

of the erosion-controlling materials in the designated plots. Seed mixture used was cultivated varieties of creeping red fescue, Festuca rubra, 40% by weight; white clover, Trifolium repens, 12%; Timothy, Phleum pratense, 24%; and Canada bluegrass, Poa compressa, 24%.

The spoil is rather coarse with more than 70% of the surface materials from 0-15 cm depth being larger than 2 mm in size (Table 1). The porous nature of the spoil coupled with the high prevailing wind renders at least the surface of the spoil droughty during considerable periods in the growing season. The fertility of the spoil is rather low, and it has a high pH (Table 1). Total nitrogen is high and is attributable to the high content of the element in the coal in the spoil (Campbell, J.D. 1970. Alberta Foothills Coal. Extracts from Alberta Research Council Reports).

B. Cover Establishment Methods with Native Grass Mixture

The experiment was established in mid-June, 1980, on a flat overburden pile in a randomized block design with eight treatments in four replications. The treatments consisted of direct seed broadcast (control), simulated drilling, straw (and nylon net) placement over broadcast seed, hydroseeding with wood fibre mulch, hydroseeding with grass mulch, seed broadcast followed by hydromulching, seed broadcast followed by the placing of excelsior blanket, and seed broadcast followed by the placing of hold/gro. (The excelsior blanket and the hold/gro were the same materials described in the previous experiment). The wood fibre mulch was applied at 2 000 kg/ha, the grass mulch at 5 000 kg/ha, and the barley straw at 5 600 kg/ha.

TABLE 1

SOME PROPERTIES OF THE SPOIL

a. CHEMICAL:

pH	EC mS/cm	TOTAL N, %	AVAILABLE NUTRIENTS, ppm				TEC me/100 g
			NH_4^+	NO_3^-	P	K	
8.4	0.2	0.56	1.5	0	1.5	34.0	9.3

b. PARTICLE SIZE DISTRIBUTION:

COARSE FRACTION, % (> 2 mm)	SOIL FRACTION, % (≤ 2 mm)			
	SAND	SILT	CLAY	TOTAL
70.9	19.2	6.1	3.8	29.1
—	66.0[2]	20.8[2]	13.2[2]	—

[1] BULK SAMPLE (EXCLUSIVE OF LARGER STONES AND ROCK FRAGMENTS)

[2] AS A PERCENTAGE OF THE SOIL FRACTION

Seeding rate was 46.1 kg/ha. The seed mixture consisted of the same number of seeds of each of the following four species, each originating from the Rocky Mountains area: slender wheatgrass (4[1]), Agropyron trachycaulum (68.1% by weight); alpine sheep fescue (144[1]), Festuca saximontana (14.5%); alpine bluegrass (153[1]), Poa alpina (9.3%); and interior bluegrass (150[1]), Poa interior (8.1%). In terms of relative seed size based on 1 000 seed weight, the mixture ratio was 8.4 : 1.8 : 1.1 : 1.0 respectively for the species. Fertilizer (10:30:10 at 600 kg/ha) was broadcast and the plots raked before applying the treatments.

The overburden pile on which the experiment was laid out was rather coarse and contained large stones and rock fragments. A mechanical analysis for the soil size component indicated it to be high in sand (Table 2). As with the spoil pile this overburden pile tested high in pH, (Table 2) and the fertility level was very low. Total nitrogen, as expected, was also low.

RESULTS AND DISCUSSION

A. Techniques of Erosion Control in Cover Establishment

The first year gave encouraging results in plant establishment in all five treatments, including the control. Moisture availability in soil plays a significant role towards achieving reclamation success, especially in harsh environments with coarse soils in the study area. Moisture content of the surface 15 cm layer of the spoil under the various treat-

[1]Selection line number (Genetics Department, University of Alberta - 1978 harvest).

TABLE 2

SOME PROPERTIES OF THE OVERBURDEN

a. CHEMICAL:

pH	EC mS/cm	TOTAL N, %	AVAILABLE NUTRIENTS, ppm					CEC me/100 g
			NH_4^+	NO_3^-	P	K	SO_4 S	
8.5	0.2	0.04	0.7	1.1	0.5	47.5	3.0	7.4

b. PARTICLE SIZE DISTRIBUTION

COARSE FRACTION, % (> 2mm)	SOIL FRACTION, % (≤ 2 mm)			
	SAND	SILT	CLAY	TOTAL
72.4	21.0	4.5	2.1	27.6
—	76.0[2]	16.4[2]	7.6[2]	—

[1] BULK SAMPLE (EXCLUSIVE OF LARGER STONES AND ROCK FRAGMENTS)

[2] AS A PERCENT OF THE SOIL FRACTION

ments, approximately two months after seeding and following relatively-substantial precipitation (31 mm) in the preceding week, was greater under the erosion control materials although the differences were not significant (Figure 1). The lower moisture content in the troughs in comparison with the control is attributable to the competition for moisture by the greater number of germinants per unit area in the troughs (the increased number of germinants is a result of seeds on the ridges having drifted into the troughs). On the other hand, the moisture content in the control suggests that the plant cover minimizes spoil desiccation by radiation and high winds as compared with bare (ridge tops) spoil.

One of the major roles of a mulch is to control excessive evaporation loss of soil moisture, and in this sense the erosion control materials used in the experiments also act as mulches. As biomass production (discussed later) was greater under the materials, the demand for moisture was expected to have been greater, and soil moisture data suggest that the materials acted effectively as mulches. In a harsh environment, especially one with the added limitation of an excessively porous growth medium, the slight increase in soil moisture level that could be obtained with the erosion control materials could mean a success in establishing cover, especially in a year with an excessive number of long, dry periods.

Spoil temperatures at 5 cm depth in the various treatments and in the developed plant cover nine weeks into the experiment during the course of one day are given in Figure 2. No extremely high temperatures were observed on a day when the highest atmospheric temperatures

Figure 1:

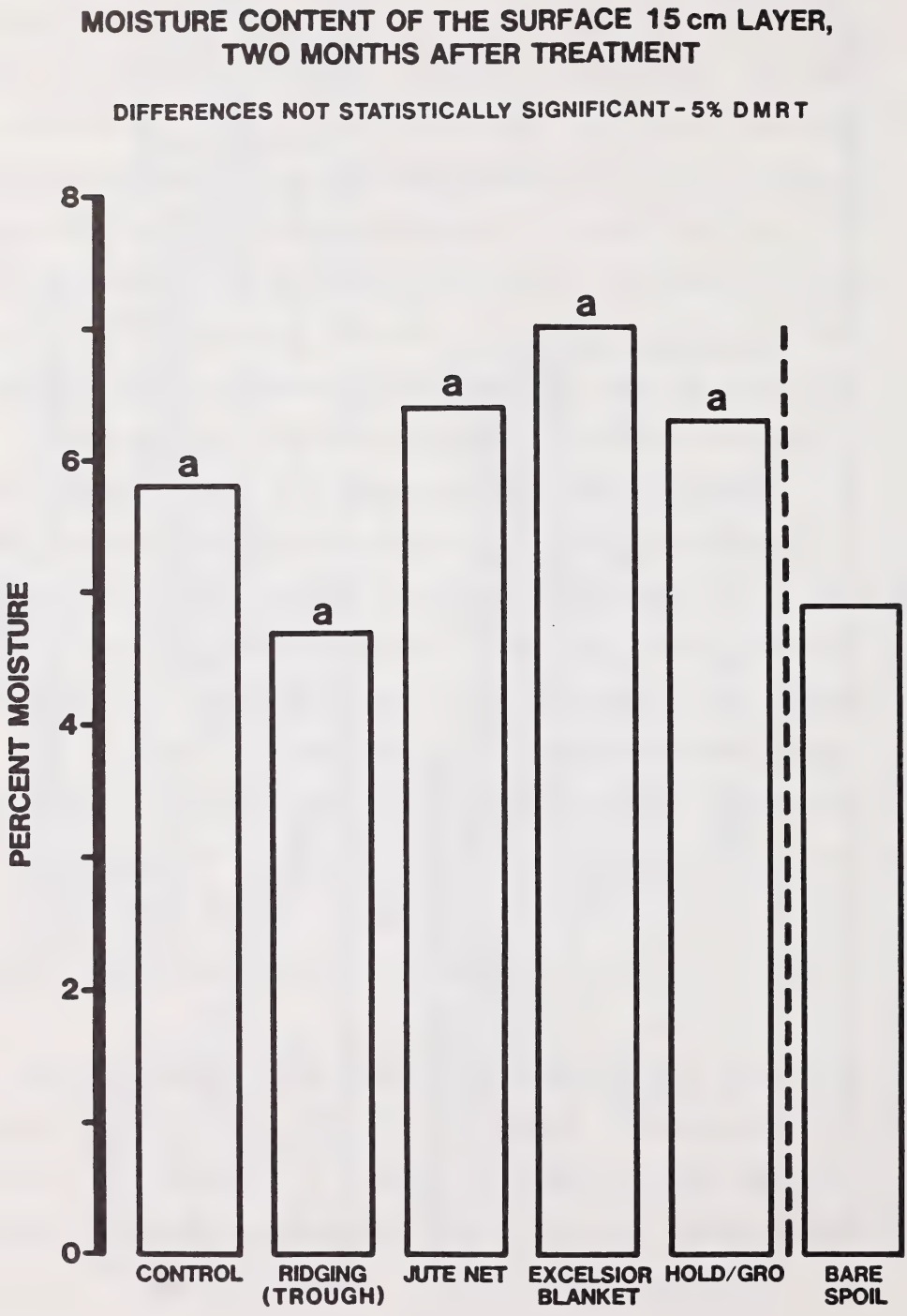
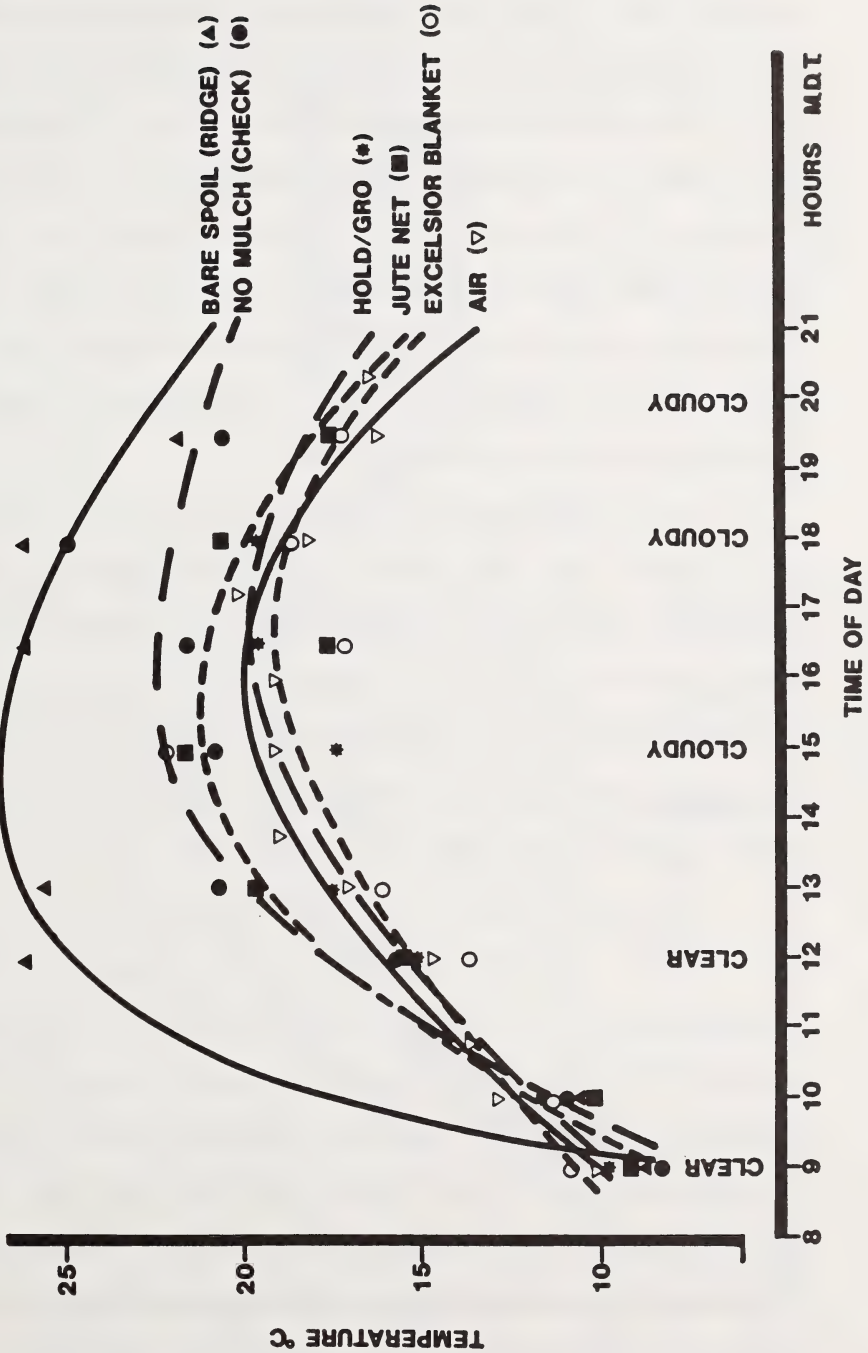

MOISTURE CONTENT OF THE SURFACE 15 cm LAYER,
TWO MONTHS AFTER TREATMENT
DIFFERENCES NOT STATISTICALLY SIGNIFICANT - 5% DMRT
PERCENT MOISTURE
8
6
4
2
0
a
a
a
a
a
CONTROL
RIDGING (TROUGH)
JUTE NET
EXCELSIOR BLANKET
HOLD/GRO
BARE SPOIL

Figure 2:

TREATMENT EFFECTS ON SPOIL TEMPERATURES (5-cm DEPTH) AUGUST 13, 1979



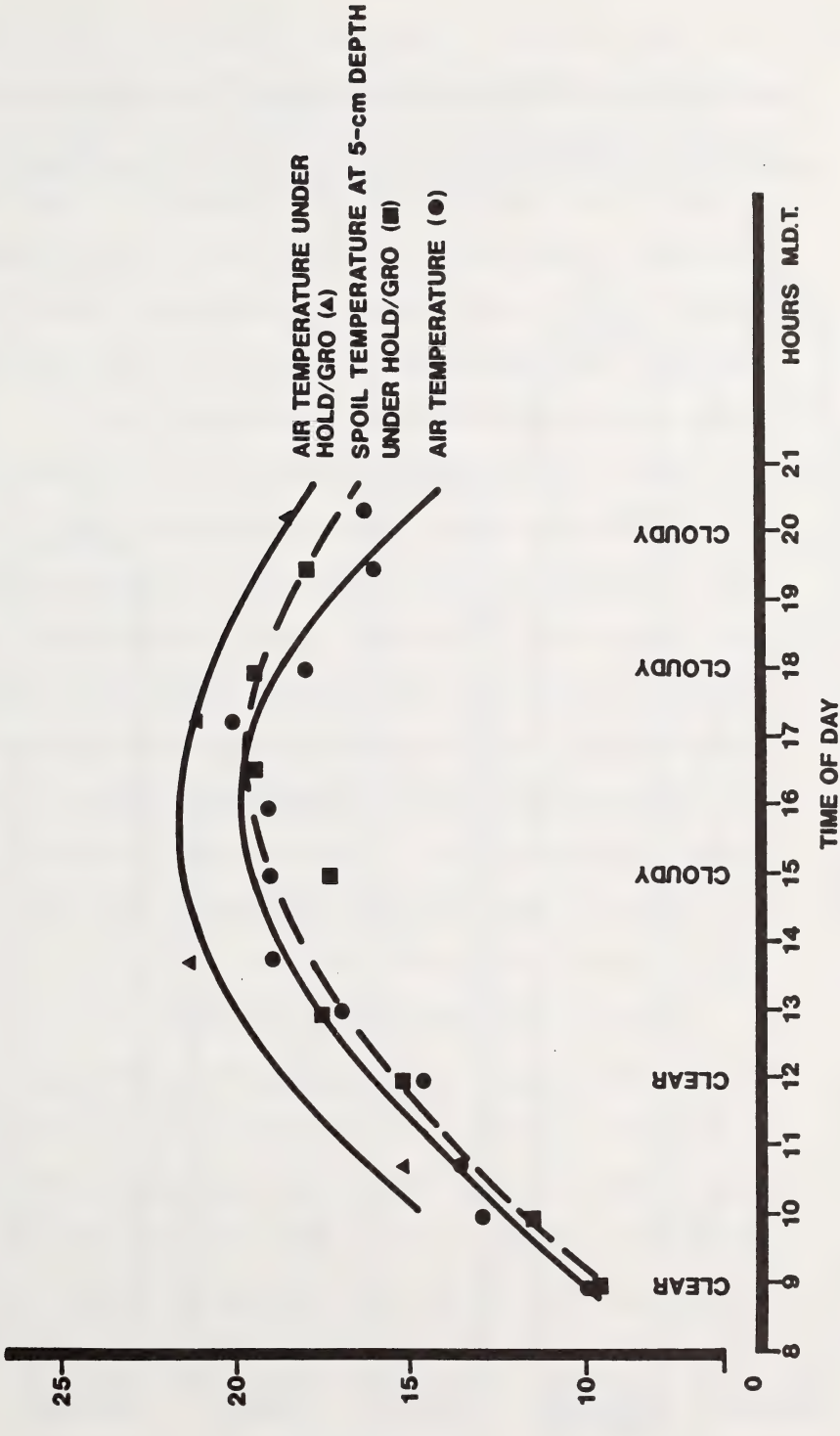
recorded at the site ranged between 18.3° and 23.1°C in a two-hour period (14:55 - 16:55 h). The average temperature was 16.2°C between 08:55 and 19:50 hours and represented a warm day on the site.

Temperatures were generally lower at the 15 cm depth than at the 5 cm depth in all treatments in the measurements made after 12:00 hours except in the excelsior blanket treatment where the earlier afternoon temperatures essentially were the same at both depths (data for 15 cm depth are not illustrated). In general, temperatures under the excelsior blanket and the hold/gro treatments were marginally higher at the 5 cm depth than under the other treatments.

The air temperature in the plant cover, under the hold/gro (which was raised by the plant cover) was slightly higher than the ambient air temperature and the spoil temperature at 15 cm depth under the hold/gro during the course of the day (Figure 3). The situation perhaps created a "green-house micro-environment" effect during some periods and thus promoted better growth, as indicated by the higher percentage of plant cover and dry matter yield (discussed later).

Although the major function of mulches has been in soil moisture conservation, they have also been used in hotter climates to keep the seedbed cooler and to regulate the variations in soil temperatures in the course of the day. In this study the excelsior blanket and hold/gro were effective in keeping the seedbed (5 cm depth) slightly cooler during the warmer periods of the day to the extent that they might have influenced seed emergence. The influence of the mulches in regulating spoil temperatures did not extend to the 15 cm depth. Temperature differences between the bare spoil and the control (with plant cover) indicated some

Figure 3: HOLD/GRO EFFECTS ON TEMPERATURES - AUGUST 13, 1979



moderating influence of the plant cover on the fluctuations in spoil temperature. Spoil temperature data collected in the mid-morning clearly suggests that the temperatures in the spoil under the hold/gro and excelsior blanket probably do not fall as much overnight as in the other treatments. This perhaps indicates that in this environment (cool, and Foothills region), seed emergence may be earlier under these two roll-out mulches. Observations on the progress in plant growth early in the season indicated that this could have been the case.

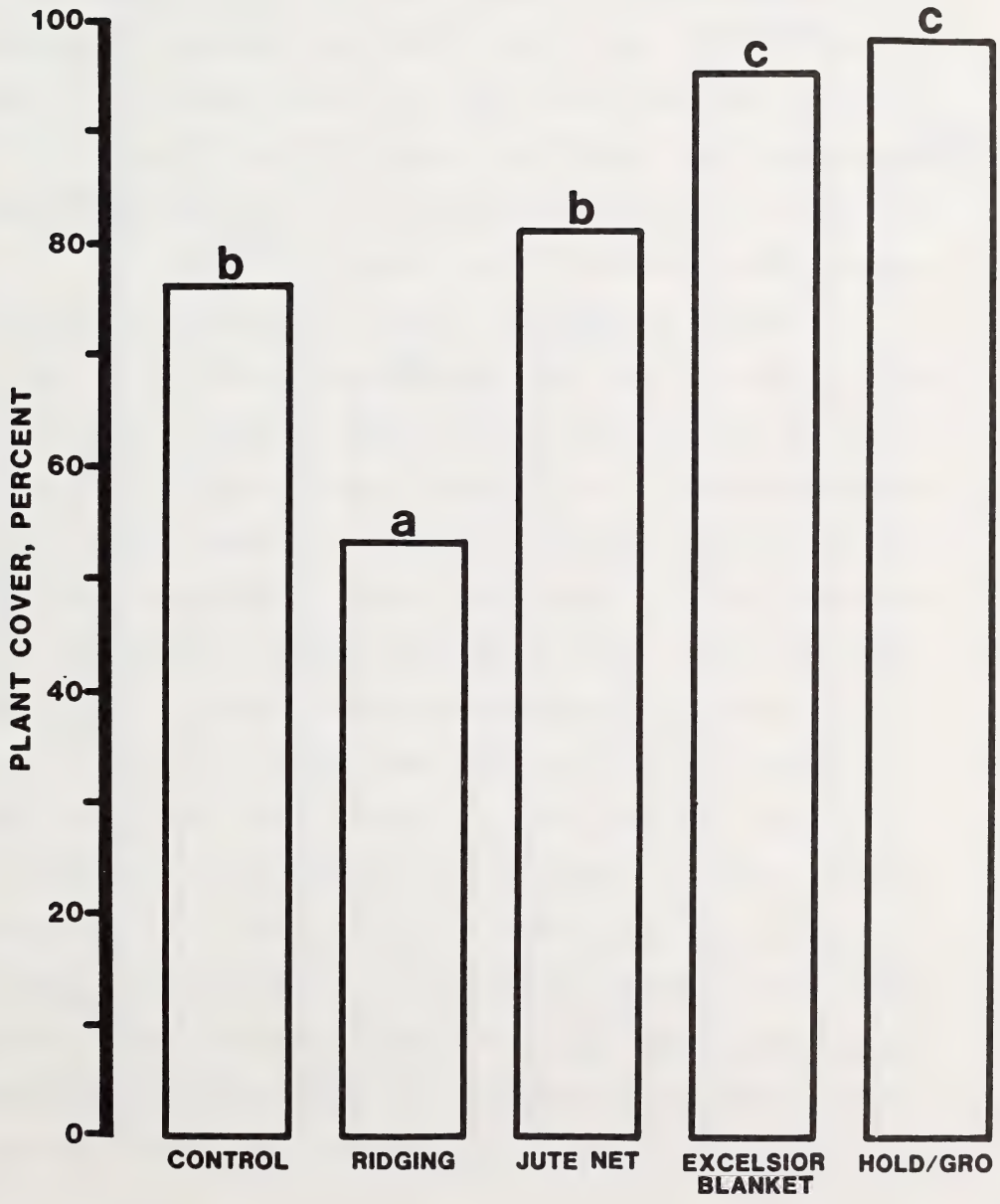
Plant cover percentages were high in all treatments at the end of the first growing season, considering the plant growth limitations of the site. Hold/gro and excelsior blanket gave the highest percentage of plant cover (Figure 4). Percentage of plant cover increased substantially in the second season with the exception of the hold/gro treatment, which had produced an almost complete plant cover in the first season. Cover was maintained at as high a level in each treatment in the third (1981) season as in the second. Cover decreased somewhat in 1982, the first year fertilizers were withdrawn, and showed substantial decrease in each treatment in the subsequent (1983) year.

Figure 4 indicates cover to be lowest in the ridging treatment, because while plants grew actively in the trough, there was little encroachment onto the crest. With time, however, the ridges are beginning to flatten out and plant cover has started slowly encroaching upon the flattened ridges. Cover within the plots has not encroached the unseeded borders between plots although the plants are producing viable seeds. This implies that in order to obtain plant cover on the abandoned

Figure 4:

PLANT COVER TWO SEASONS (1980) AFTER SEEDING

SAME LETTERS INDICATE NO SIGNIFICANT DIFFERENCES - 5% D.M.R.T.



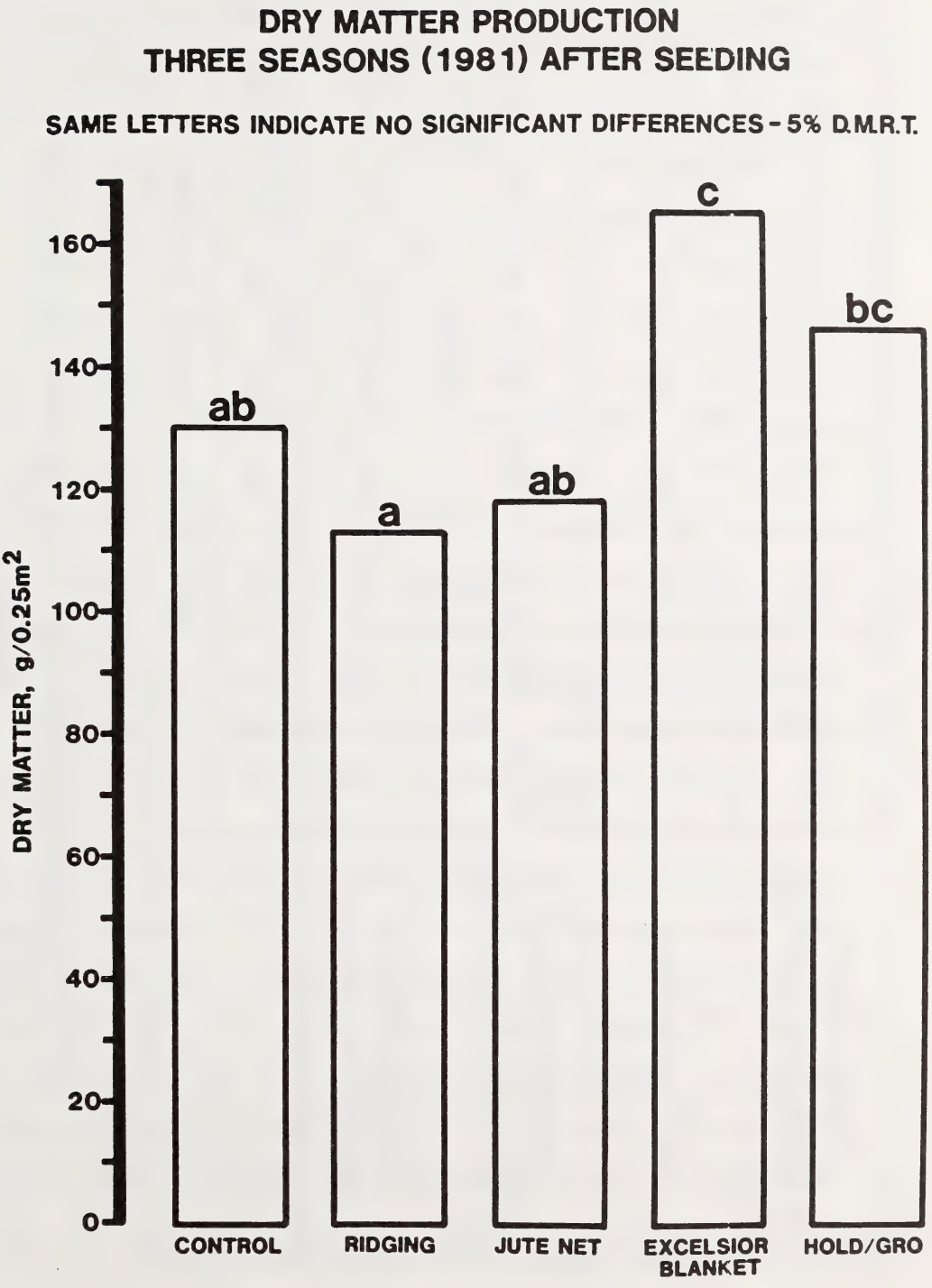
mine nature needs assistance, especially in spoil-surface manipulation to anchor these seeds.

As expected, dry matter production in the first season was low; considering the environment, however, production was acceptable, as was the case with plant cover. Hold/gro gave the best dry matter production in the first year. While the experiment was fertilized, production increased substantially in the second season in all treatments, and the same high levels were continued into 1981 (Figure 5). Production began to show some decline in 1983, the year after fertilization was stopped (data for 1982 and 1983 not shown).

Production was more than doubled in the second year and remained high in the third year under the excelsior blanket and jute net treatments, as was the case in the control. Although hold/gro gave the highest production in the first year, the increase in the subsequent year was low; however the level of production remained high in the second and third years. There were clearly no significant differences in production under the erosion-control materials, and the jute net was much more effective than ridging or the control in the subsequent years.

During the first year, the plants could not effectively penetrate the hold/gro and grow above it. This did not seem to have affected growth; it rather created a "greenhouse micro-environment" which explains the high production level in the treatment. The high production levels in the excelsior blanket and the hold/gro are attributable to the higher spoil moisture status. Since the tops of the ridges in the ridging treatment were free of plant cover, the high production in this treatment since the second year is also due primarily to the moisture status in the troughs.

Figure 5:


DRY MATTER PRODUCTION
THREE SEASONS (1981) AFTER SEEDING
SAME LETTERS INDICATE NO SIGNIFICANT DIFFERENCES - 5% D.M.R.T.
DRY MATTER, g/0.25m2
0
20
40
60
80
100
120
140
160
ab
a
ab
c
bc
CONTROL
RIDGING
JUTE NET
EXCELSIOR BLANKET
HOLD/GRO

The extent of erosion in the plots would depend on the amount and intensity of rainfall. We were able only to measure the total precipitation over given periods. Total precipitation was low during the germination and cover establishment phase of the study (Table 3), resulting in a lesser degree of surface run-off; hence few erosion problems occurred. Most of the precipitation (62%) occurred in the last third of the season.

There was hardly any erosion in the excelsior blanket and hold/gro treatments in the first season (Figure 6); however, in some of the plots, the hold/gro and the plant cover under it were subjected to burying by spoil which was moved downslope by flowing water originating outside the plots. Erosion in the jute net treatment was minimal, but some burying occurred, as with the hold/gro. Thus none of the roll-out mats, with the possible exception of the excelsior blanket, could be considered effective in stopping spoil material, which was carried in flowing water originating elsewhere on the slope, from burying the establishing plant cover. Erosion in the ridging treatment was minimal; here, however, the spoil which was eroded from the sides of the ridges buried portions of plant cover in the troughs. In one replication, gully erosion originating outside the experiment area filled the first trough with spoil and overflowed it, and the gully subsequently continued through the plot. Most, and probably all of the 36 mm of precipitation (Table 3) recorded between August 21 and 27, 1979, occurred on August 25, perhaps all of it occurring within two hours. Minor sheet erosion, minor gullying, and severe rill erosion on the slope on which the experiment was located suggests that the precipitation received that day

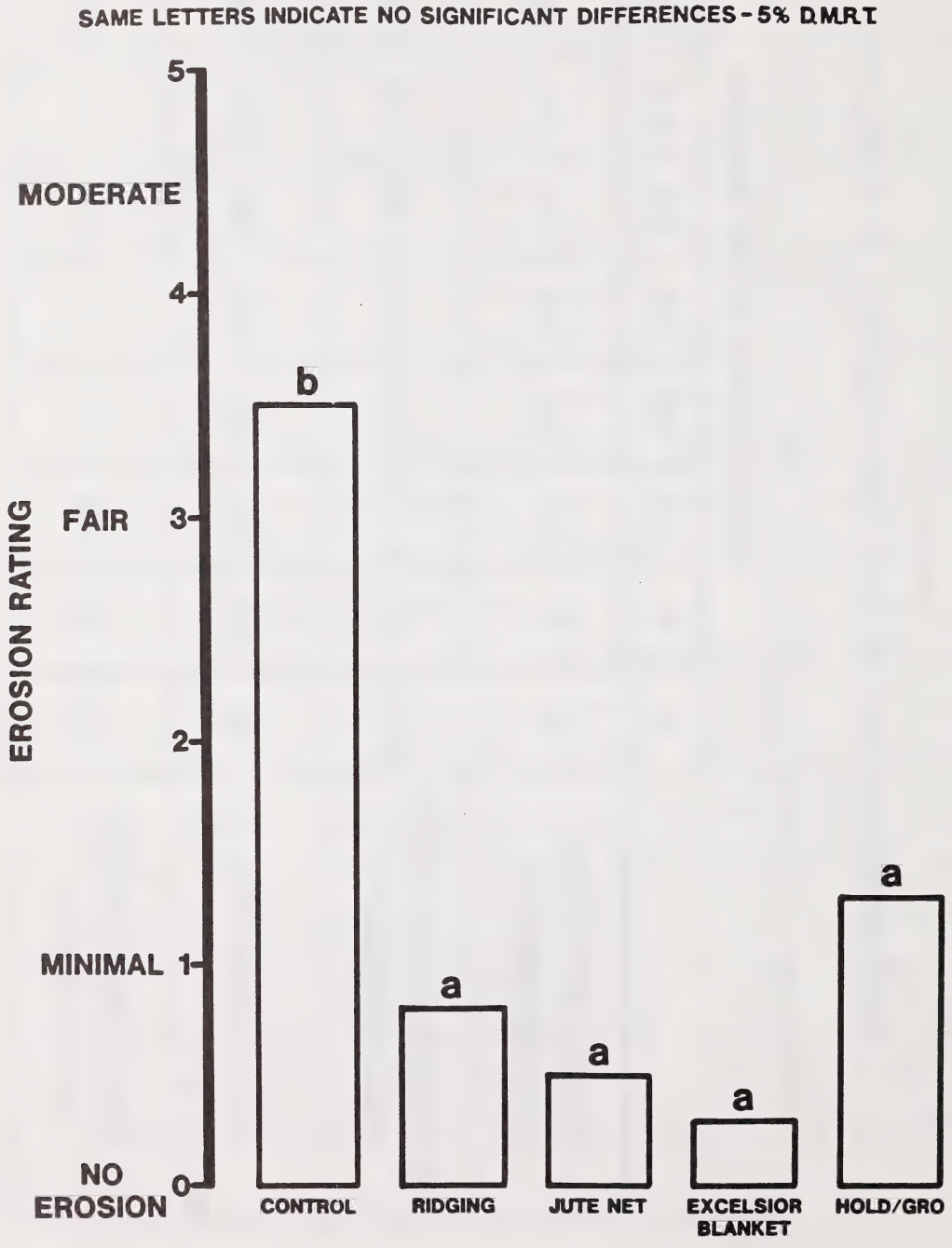
TABLE 3

PRECIPITATION (mm) IN THE FIRST SEASON OF GROWTH

	NO. OF DAYS AFTER SEEDING								
	1	9	27	35	54	61	67	75	81
TOTAL, BETWEEN MEASUREMENTS	9	6	21	14	29	31	3	44	36
MEAN DAILY, BETWEEN MEASUREMENTS	9.00	.75	1.17	1.75	1.52	4.43	.50	5.50	6.00
ACCUMULATIVE	9	15	36	50	69	100	103	147	183
% MOISTURE CONTENT (BARE SPOIL)	8.8	—	3.6	—	—	4.9	—	3.4	—

Figure 6:

EROSION RATINGS THREE SEASONS (1981) AFTER TREATMENT
OCULAR RATING: 0 (NO EROSION) TO 9 (VERY SEVERE EROSION)



was of high intensity. In the long term, the excelsior blanket and the jute net were best in controlling erosion (Figure 6).

The observation for this abandoned mine on which the piles have remained relatively stable for many years is that any erosion is storm induced and that for a given season a single storm could account for all the significant erosion. Because snow cover is virtually non-existent on the experimental site, erosion associated with snowmelt run-off on the pile is minimal.

There are other aspects of the experiment such as differences in fertility and nutrient levels in the plant materials on which data have been collected, especially since fertilization was stopped in 1982. Time allotted for this paper allows primarily for the discussion of the revegetation aspects of the experiment.

B. Native Grass Cover Establishment

In the trial involving plant cover establishment on an extremely harsh site with a seed mixture composed of native grasses of considerable seed-size differences, the results indicate that seed emergence is a significant factor to be considered in the choice of a seeding method. Our experience with native grasses in other trials on two abandoned mines in the foothills showed that with native grasses there is virtually no plant cover establishment to be expected in the first season. In the first season, germination for some grass species was not complete. In this trial, plant cover was essentially non-existent as germination was not complete and the germinants were still tiny at the end of the first season.

Because of the types of treatment in the trial, germinant count was not possible but a germination rating revealed considerable differences due to treatments (Figure 7). Germination was best in the excelsior blanket treatment, closely followed by simulated-drilling and in a distant second place by treatments involving seed broadcasts with the placement of a protective cover of hold/gro, straw or wood fibre hydromulch. Hydroseeding with grass mulch or wood fibre mulch, or seed broadcast gave low germination ratings. It was not possible to rate the degree of germination under the straw as most germinants were still under it. The Agropyron was observed to have the highest degree of germination. Early in the second season (Figure 7) the germinants in the excelsior blanket and straw treatments began to be more conspicuous, and the germination in the excelsior blanket rated even better than in simulated drilling.

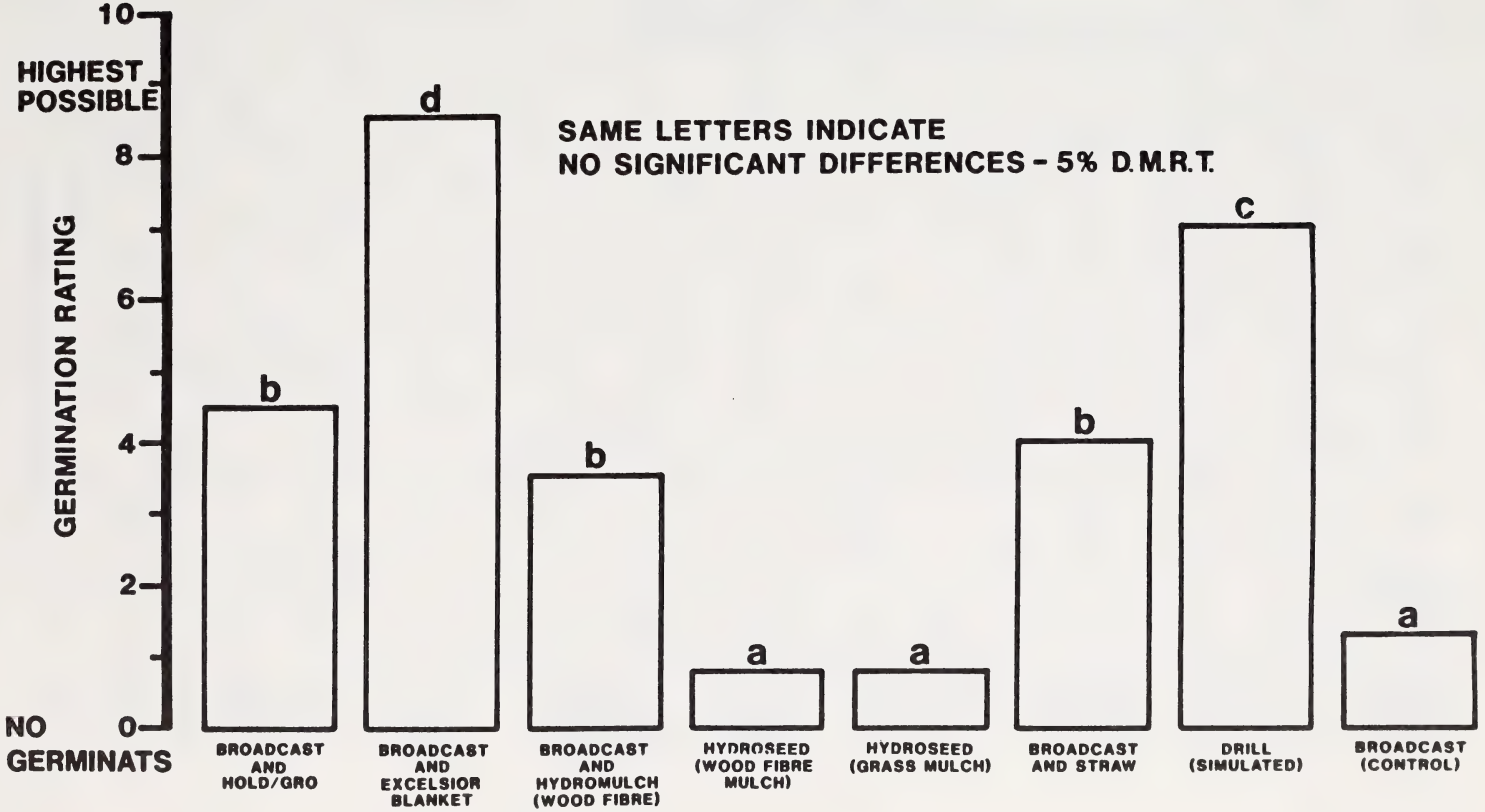
The high winds at this very exposed experimental site had a significant influence on the extent of the number of germinants in most of the treatments. Observation confirmed that the grass seeds were not adequately protected in some treatments and thus were lost in the wind. In the wood fibre mulch and grass mulch hydromulching, treatments to which tackifying agents were added, it was noticed that as the materials dried up, pieces or lumps were dislodged in the high-velocity gusts, resulting in seed losses.

As had been expected, based on observations from earlier experiments, plant cover at the end of the second growing season was low as compared with agronomic grass sown at the same mine two years earlier.

Figure 7:

NATIVE GRASS MIX GERMINATION RATINGS EARLY IN THE SECOND GROWING SEASON - 1981

RATING: 0 (NO GERMINANTS) THROUGH 9 (HIGHEST GERMINANTS POSSIBLE)



Percentage of plant cover was best with the placement of straw or excelsior blanket after seed broadcast, and with simulated drilling (Figure 8). These three treatments provided the best protection from seed loss through the high winds on the site. The low percentage of plant cover with hold/gro suggested seed loss was considerably higher than expected as openings in the material allowed the wind to dislodge the seed. All other treatments produced poor plant cover, primarily because of the loss of the protective material (wood fibre or grass mulch) and seed to the high winds. The plant densities in Figure 9 partly support the seed loss argument. Other factors such as moisture and temperature differences in the seed beds brought about by the treatments also accounted for the different levels of seed germination. The relatively-low density count in the simulated drilling (Figure 9) suggests that the 2 cm seeding depth was not adequate to prevent the loss of smaller seeds (three species) to the high winds or that the drilling was too deep for germination of these small seeds. This question of depth of seeding small native grass seeds requires further study.

Density counts ratios by species given in Figure 10 for the treatments which produced the best plant cover and broadcast seeding (control) indicate that although the same numbers of seeds per species were in the seeded mix, the seed size played an important role in the actual counts as shown also in Table 4. Densities under the excelsior blanket treatment indicate that where a good mixture of native grasses of different seed sizes is preferred, this treatment is the best for at least the very harsh sites. There is a definite need to undertake further

Figure 8:

NATIVE GRASS PLANT COVER
AT THE END OF THE SECOND (1981) GROWING SEASON

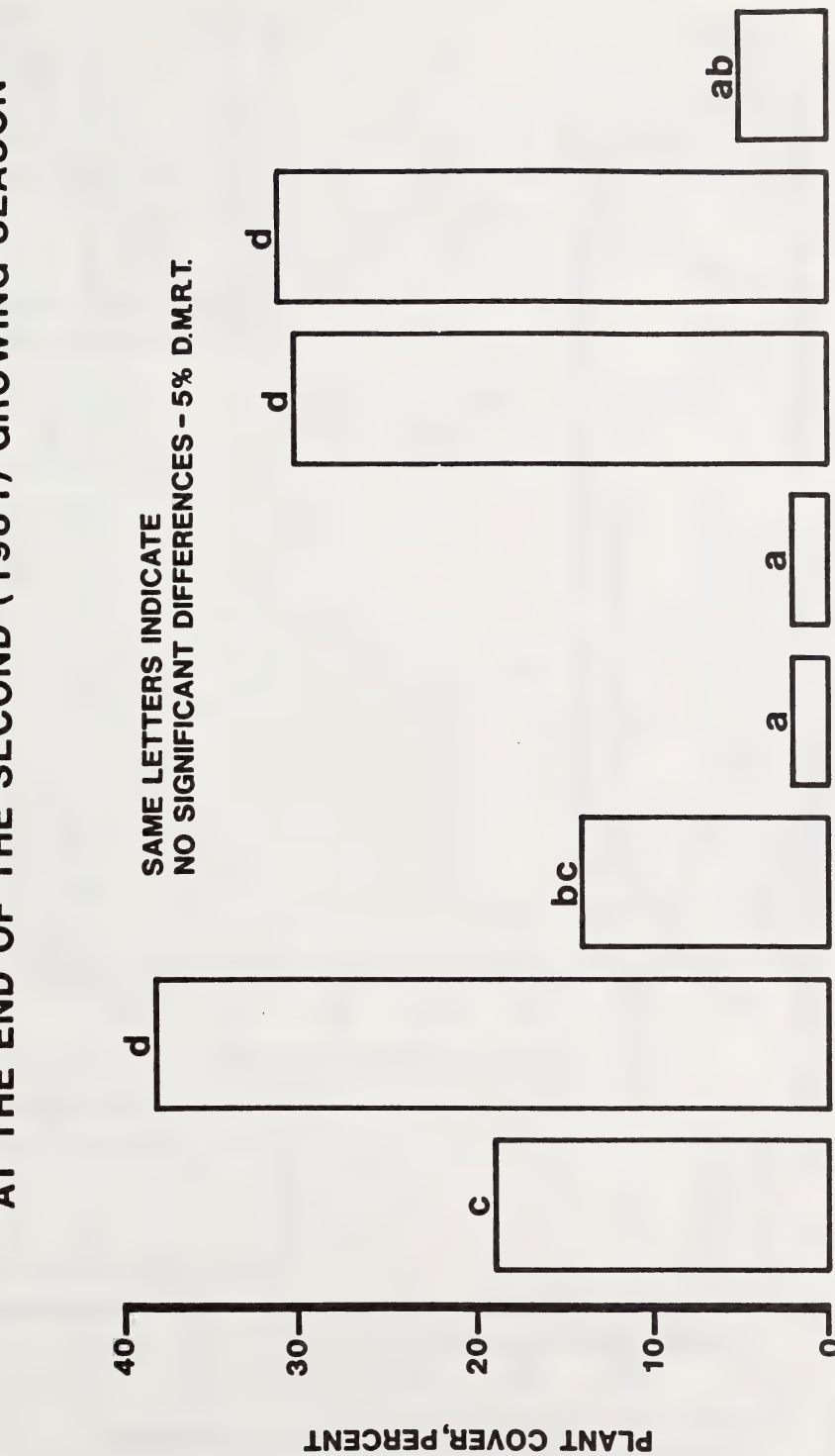


Figure 9:

NATIVE GRASS PLANT DENSITIES AT THE END OF THE SECOND (1981) GROWING SEASON

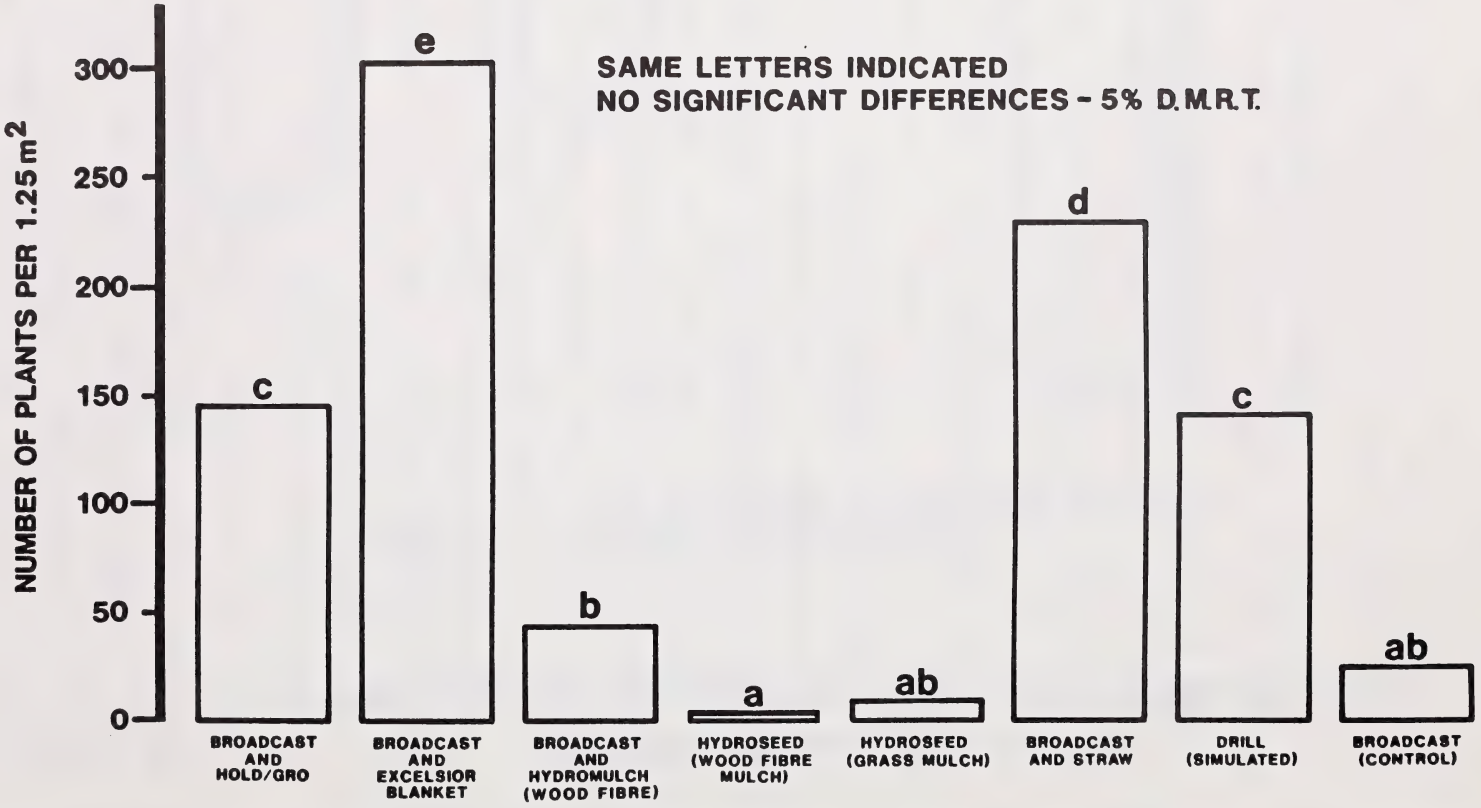


Figure 10: PLANT DENSITY RATIOS BY SPECIES IN SELECTED TREATMENTS IN RELATION TO THE RATIOS OF THE WEIGHTS OF THE SPECIES SOWN TWO SEASONS AFTER SEEDING

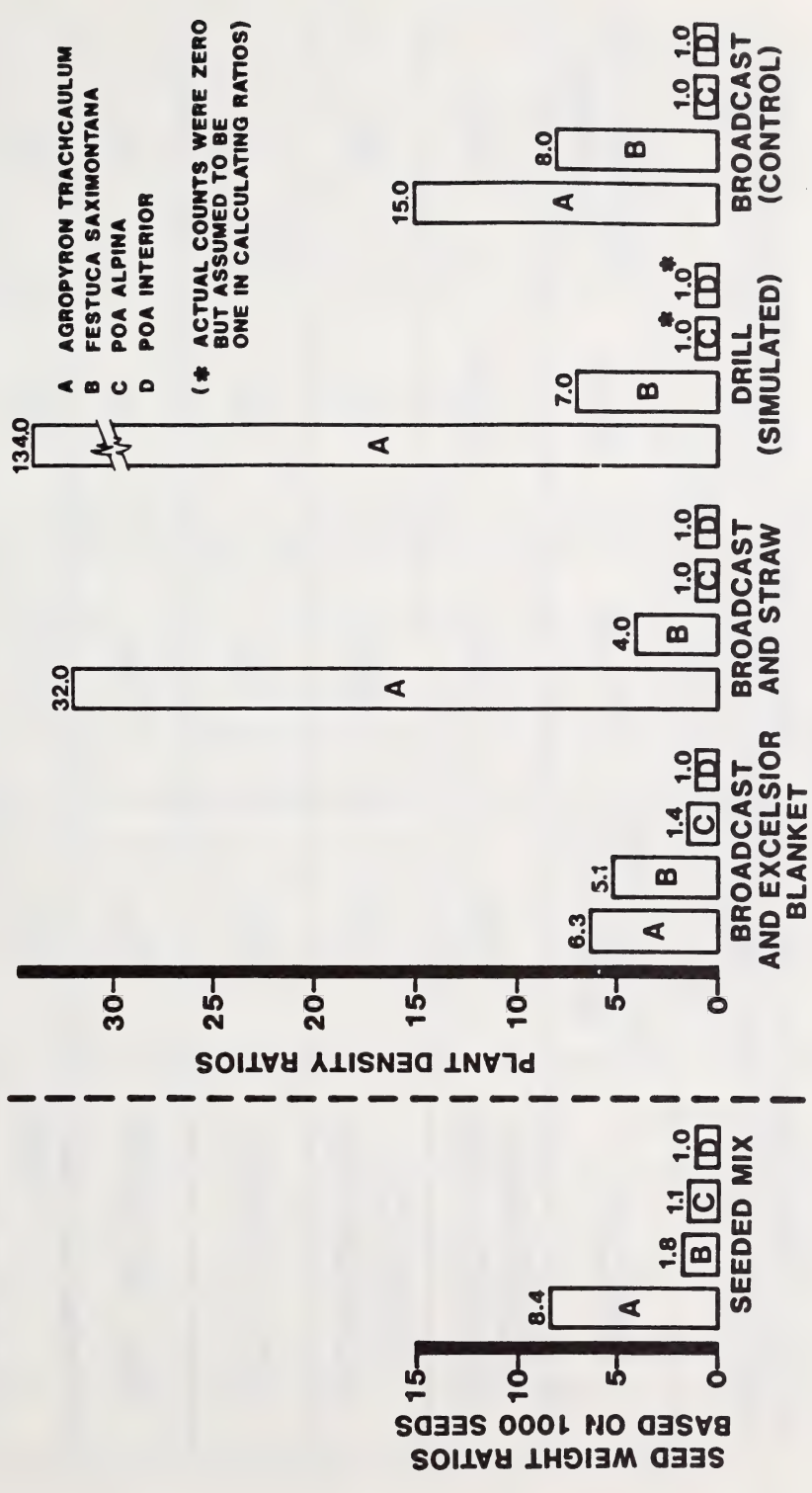

A AGROPYRON TRACHCAULUM
B FESTUCA SAXIMONTANA
C POA ALPINA
D POA INTERIOR
(* ACTUAL COUNTS WERE ZERO BUT ASSUMED TO BE ONE IN CALCULATING RATIOS)
SEED WEIGHT RATIOS BASED ON 1000 SEEDS
PLANT DENSITY RATIOS
SEEDED MIX
BROADCAST AND EXCELSIOR BLANKET
BROADCAST AND STRAW
DRILL (SIMULATED)
BROADCAST (CONTROL)

TABLE 4

PLANT DENSITIES IN THE THREE TREATMENTS PROVIDING THE BEST PERCENT COVER AND BROADCAST SEEDING - # OF PLANTS/1.25 m^2 (SECOND GROWING SEASON)

SPECIES	EXCELSIOR BLANKET	STRAW	DRILL	BROADCAST (CONTROL)
AGROPYRON TRACHCAULUM	138b	192b	134b	15c
FESTUCA SAXIMONTANA	112b	24a	7a	8b
POA ALPINA	31a	6a	0a	1a
POA INTERIOR	22a	6a	0a	1a
TOTAL	303	228	141	25

MEANS IN A GIVEN COLUMN FOLLOWED BY THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT - 5% DMRT.

studies to identify seed mixture ratios which will ensure good mixed stands of native grasses. In this experiment, the Agropyron was the dominant species on this harsh site; in other situations, other desirable species such as F. saximontana or a balanced grass cover may be preferred.

CONCLUSIONS

As stated earlier, plant cover is recognized as the important component for the determination of adequate reclamation of disturbed land, especially in erosion problem areas. Its successful establishment is an important objective in the studies reported here. One underlying objective of the studies is that the recommended methods of cover establishment on drastically disturbed sites difficult to revegetate be practical for operational conditions, and at the same time impose very little or no cost restriction to the operation. Results of these studies, which did not analyse the costs involved, indicate that revegetation of harsh sites in the alpine and subalpine areas of the Rockies in Alberta is possible with the appropriate choice of cover establishment technique for both cultivated grasses and legumes, and native grass seed mixtures.

Results obtained have emphasized the ameliorative effects of the materials used in establishing cover on harsh sites, especially in the study with native grass mixtures. It has been demonstrated that certain techniques are essential to improve conditions on the harsh sites to a minimum level to achieve plant cover establishment and support plant

growth. Through the choice of an appropriate establishment method native grasses of alpine and subalpine origins in appropriate seed mixtures can be successfully established on high-elevation severe-disturbance sites in Alberta. Because of the length of the growing season, acceptable ground cover cannot be achieved in the first year of seeding. There is certainly the need to develop appropriate native grass mixtures to ensure some diversity in species on a site to be reclaimed with native grasses. The seeding methods studied here have clearly shown that in native grass seed mixtures composed of species with seeds of considerable seed-size differences, conditions created in the seedbed favoured dominance by the large-seeded grass species. Hydroseeding with a wood fibre or grass mulch was not as effective on this site with high winds as methods involving the physical anchoring down of a protective material such as excelsior blanket or straw.

In the use of techniques of erosion control in cover establishment with cultivated grasses and legumes, results indicated that acceptable plant cover could be achieved in the season of sowing; the degree varied with the technique. Percentage of plant cover achieved in the first season was best in the mulches, especially hold/gro and excelsior blanket. Each of the establishment techniques employed was effective in controlling the little erosion which occurred as compared with a control, but none was effective in preventing spoil-bearing water that was flowing downslope from burying the material and the vegetation, as was the case in the single largest storm in the first growing season. The same was true with ridge construction across the slope. The possible exception was the excelsior blanket.

The high percentage of plant cover and dry matter production with hold/gro in the first season are attributable to the "greenhouse micro-environment" effect, the result of a restricted warm air flow under the material which is supported by the plants beneath. Under harsh site conditions, and especially in northern environments where the growing season is short and seeding could be as late as early summer, hold/gro is a promising material for achieving earlier growth, especially of the slower plant species. While the materials used proved effective in a situation of normal erosion problems, the data collected indicated that moisture conservation in the spoil was enhanced even in the pervious material. The effects of the materials on spoil temperatures suggested that it is possible to effect earlier seed emergence in late spring when frosts are frequent in the area, as the surface soil may not freeze so readily and therefore the surface temperatures may not fluctuate widely between days and nights.

The two studies covered in this paper are now in a monitoring phase. Maintenance fertilization has been withdrawn in one study for two seasons and in the other, starting this season. Data are being collected primarily in plant cover changes, biomass production, changes in nutrient levels in the spoil and overburden, and the biomass. These will be reported in due course.

REFERENCES

Takyi, S.K. 1980. Influence of Roll-out Mats and Ridging on the Establishment of Plant Cover on an Unamended Coal Spoil - A Progress Report for 1979. ENR Report No. T/20-79. Alberta Department of Energy and Natural Resources, Alberta Forest Service, Edmonton.

____. 1981. Methods of Establishing Native Grasses on Coal Overburden. First Year Report (1980). Alberta Department of Energy and Natural Resources, Alberta Forest Service, Edmonton.

____. 1984. Role of Topsoil, Fertilizers and Companion Crops in Revegetation of Two Severe Sites in the Alberta Foothills and Mountains. ENR Report No. T/67. Alberta Department of Energy and Natural Resources, Alberta Forest Service, Edmonton.

Takyi, S.K. and Leitch, R.H. 1981. Influence of Roll-out Mats and Ridging on the Establishment of Plant Cover on an Unamended Coal Spoil - A Progress Report for 1980. ENR Report No. T/20-80. Alberta Department of Energy and Natural Resources, Alberta Forest Service, Edmonton.

Natural Vegetation and Ecology of Abandoned Coal-Mined Land at Sterco-Coal Valley, Rocky Mountain Foothills, Alberta.

William B. Russell

INTRODUCTION

While there is a large and growing body of reclamation literature that is relevant to Alberta (see Sims and Powter 1982), little has been published on the natural revegetation of coal-mined lands in Alberta. Root (1976) briefly described the natural vegetation on the Cadomin (east) abandoned coal mine. Schumacher et al. (1977) investigated plant succession on abandoned coal-mined land in the aspen parkland of central Alberta. Russell (1980) studied the natural vegetation and ecology of two abandoned coal mines near Mountain Park. Russell (1980) also described and compared the vascular plant floras of the major abandoned coal mines in the Coal Branch Region.

This paper describes a study of the natural vegetation and ecology of the abandoned coal mines at Sterco and Coal Valley. The study objectives were:

1. to classify and describe the vascular plant communities;
2. to relate trends in total plant cover, species richness, and species abundance with edaphic factors; and
3. to evaluate the effects of slope position on total plant cover, species richness, and species abundances.

All field work was done during the summers of 1975 and 1976.

STUDY AREA

Sterco and Coal Valley are ca. 60 km SW of Edson in the foothills of west-central Alberta (NE 1/4 T-47 R-20 W5; el. 1408 m). The two abandoned mines are adjacent one another. The spoil-heaps and strip-pits continue in an east-west direction for ca. 5 km. New mining (after this study was made) by Luscar Sterco (1977) Ltd. has since increased the area covered by spoil-heaps.

Sterco and Coal Valley are the oldest strip-mines in the region. Stripping began in 1918 at Sterco and 1922 at Coal Valley. Large steam shovels and draglines were used to excavate the coal. Extensive spoil-heaps were created. Most spoil-heaps were levelled off on top and have steep banks. Sterco was abandoned in 1954 and Coal Valley in 1955 (Lake 1967).

The climate of the area is humid continental with cold winters, cool short summers, and freezing temperatures possible in any month. At Nordegg (83 km SE of study area; el. 1326 m) the mean annual temperature is 0.7°C, mean temperature for January is -14.1°C and July is 12.6°C, and mean annual precipitation is 555 mm, of which 181 mm is snowfall (Alberta Environment 1982). The seasonally operated meteorological station at Lovett (6 km from study area) receives an average of 85, 111, 98 and 94 mm of precipitation for May, June, July, and August, respectively (Alberta Environment 1982).

The coal seams and enclosing strata mined at Sterco and Coal Valley are included in the Saunders Formation and are of Paleocene Tertiary age (Allen and Rutherford 1924). These strata consist of interbedded sandstones, siltstones and mudstones, impersistent conglomerates, volcanic ash beds, and coal seams of varying thickness. The sandstones are rather coarse-grained and cross-bedded. The mudstones are generally greenish-grey and frequently silty (Alexander 1977).

The study area lies on the border between the boreal foothills and boreal uplands ecoregions of Strong and Leggat (1981). Lodgepole pine (Pinus contorta) is the distinctive tree species. Climax stands on mesic upland sites are theoretically dominated by white spruce (Picea glauca). The boreal foothills forms the extensive eastern part of the boreal-cordilleran transition zone. The presence of aspen (Populus tremuloides)

and balsam poplar (Populus balsamifera) as major tree species distinguishes these forests from those in the boreal uplands. The vegetation of the region has been described by Lesko and Lindsay (1973) and Hardy Associates Ltd. (1980).

METHODS

Field Sampling

Twenty-four stands of varying size ($\overline{X}$ = 402 m^2) were chosen to sample the range of vegetation and spoils. The stands were relatively homogeneous, i.e. without apparent discontinuities in plant cover, species composition, topography, and soils. Stands for which preliminary estimates of total plant cover were <1% were inventoried. Canopy cover was estimated in cm^2 for all vascular species, for total bryophytes, and for total lichens using a metric ruler. Stands for which preliminary estimates of total plant cover exceeded 1% were sampled using randomly placed 2x2 m quadrats. Canopy cover was estimated for all vascular species, total bryophytes, and total lichens in each quadrat. A stand was considered adequately sampled when the standard error/mean was <20% of total plant cover and < 30% for cover of the species with the highest cover.

Four randomly located soil pits were dug to a minimum depth of 30 cm each of the stands. General notes were made on horizon development, structure, surface crusting, and erosion. Spoil samples were collected from three depths in each pit (0-5, 13-18, and 25-30 cm) and bulked by depth, resulting in three composite samples per stand.

To evaluate the influence of slope position on vegetation, 20 transects were run down the sides of spoil-heaps, perpendicular to the contours. Six 2x2 m quadrats were placed along each transect, one at each major slope position: top, crest, upper-slope, mid-slope, lower-

slope, and base. In each quadrat canopy cover was estimated in cm^2 for all vascular species, total bryophytes and total lichens. The transects were located on the spoil-heaps using a stratified random sampling procedure (see Russell 1980).

Laboratory Analyses

The vegetation data were synthesized using the tabular method of Mueller-Dombois and Ellenberg (1974). Floristic similarity of the stands was determined by calculating Sørensen's (1948) coefficient of community similarity index for all stand pairs. Community classification was accomplished subjectively with the aid of the vegetation synthesis table and the matrix of stand similarity indices. Spearman rank-order correlation coefficients were calculated among total plant cover, species richness, and all edaphic variables.

The communities were given binomial names. The first species in the name was the leading dominant and the second was the most abundant character species. Character species are those which show a distinct maximum concentration (quantitatively and by presence) in a community (Mueller-Dombois and Ellenberg 1974).

Separate Friedman tests (ANOVA by ranks; Daniel 1978) were conducted on the transect data to determine the effects of slope position on total plant cover and species richness. A multiple comparison procedure, recommended by Daniel (1978) for use with the Friedman test, was used to determine the significance of differences in cover and richness among the slope positions. To evaluate the effects of slope position on individual species, species quadrat frequencies were calculated for each slope position.

The air-dried spoil samples were ground, if necessary, passed through a 2 mm sieve, and the < 2 mm and > 2 mm fractions weighed. Ocular estimates were made of the volume percentage of the different rock types in the > 2 mm fraction of the surface (0-5 cm) spoil samples The following spoil properties were determined using the laboratory methods detailed in Russell (1980): percent sand, silt, and clay; available water holding capacity, expressed on a whole soil basis; pH; electrical conductivity; exchangeable NH_4-N and NO_3-N; available P_2O_5; and available K. Spoil properties were compared between the coal and mudstone dominated spoils using the Wilcoxon two-sample test (Daniel 1978).

RESULTS AND DISCUSSION

Spoils

The spoils were variable in composition but generally may be grouped into two types:

1. coal dominated spoils, and
2. mudstone and sandstone dominated spoils;

hereafter referred to as coal spoils and mudstone spoils, respectively (Table 1).

There was little or no apparent horizon development in either the coal or mudstone spoils. A thin litter layer was noted in a few depressional areas associated with high plant cover on the coal spoils. Mottling was noted in some mudstone spoil pits, indicating reducing conditions during some period of the year.

Fine earth content (FEC; fraction < 2 mm) ranged from 28 to 89% and was significantly higher in the mudstone spoils than coal spoils (Table 1). FEC decreased with depth in the coal spoils, suggesting that weathering has been greater near the surface, but varied little with depth in the mudstone spoils.

Table 1. Some chemical and physical properties of the coal dominated and mudstone dominated spoils. Properties were compared between the two spoil types using the Wilcoxon two-sample test.

Spoil Property	Depth (cm)	Coal Spoils N	Coal Spoils $\bar{X}$	Mudstone Spoils N	Mudstone Spoils $\bar{X}$	Wilcoxon Test
pH	0-5	13	6.6	11	8.4	***
	13-18	12	6.4	11	8.5	***
	25-30	13	6.4	11	8.5	***
Available Plant Nutrients (ppm)						
NH_4-N	0-18	25	2.8	22	1.6	**
NO_3-N	0-18	25	1.2	22	0.8	NS
P_2O_5	0-18	4	2.1	16	0.1	**
K	0-18	4	85	16	168	*
Electrical Conductivity (mmhos/cm)	0-5	13	0.46	11	1.15	*
	13-18	12	0.07	11	0.87	NS
Fine Earth Content (%)	0-5	13	64	11	74	**
	13-18	12	41	11	72	***
	25-30	13	40	11	71	***
Rock Types in >2mm Fraction (%)						
Coal	0-5	13	92	11	6	***
Sandstone	0-5	13	<1	11	20	***
Siltstone and shale	0-5	13	7	11	74	***
Others	0-5	13	<1	11	<1	NS
Available Water Holding Capacity (%)	0-5	13	4.2	11	12.8	***
	13-18	12	3.4	11	13.5	***
Particle Size Distribution (%)						
Sand	0-5	13	79	11	36	***
	13-18	12	79	11	38	***
	25-30	13	82	11	38	***
Silt	0-5	13	10	11	34	***
	13-18	12	10	11	33	***
	25-30	13	9	11	34	***
Clay	0-5	13	10	11	30	***
	13-18	12	11	11	29	***
	25-30	13	9	11	28	***

*Differences between the two spoil types are significant at $P \leq 0.05$; **$P \leq 0.01$; ***$P \leq 0.001$; NS not significant ($P > 0.05$).

The coal dominated spoils were gravelly loamy sands and sandy loams with loose, single grain structure. The mudstone spoils were finer textured and generally had massive structure; clay loams, loams, and sandy clay loams predominated. Spoil-heaps covered by the mudstone spoils were often severely eroded. Erosion gullies as deep as 1 1/2 m were found. In dry weather a hard surface crust forms on some mudstone spoils, increasing run-off and probably inhibiting plant establishment.

Available water holding capacity was generally low in the coal spoils (1.1 to 7.6%), but significantly higher in the mudstone spoils (4.0 to 21.6%) due to the finer textures. Spoil pH's ranged from 5.0 to 9.1 and were significantly higher in the mudstone spoils.

Electrical conductivities were < 1 mmhos/cm in the coal spoils, indicating non-saline conditions, but moderately high in some mudstone spoils (up to 4.3 mmhos/cm). Salt crusting was commonly observed on the surface of the mudstone spoils.

The Alberta Soil and Feed Testing Laboratory considers NO_3-N levels < 10 ppm, P_2O_5 levels < 12.5 ppm, and K levels < 75 ppm to be low for the growth of most agricultural crops. Using these guidelines, the available NO_3-N and P_2O_5 levels were low in both spoil types. Potassium was more variable, becoming quite high in some mudstone spoils.

Vegetation

After a minimum of 20 years since abandonment the minesite vegetation was variable in composition and structure and was still sparce in many areas. Total plant cover in stands ranged from 0.05 to 50.0% and species richness (number species/100 m^2) from 1 to 15. For the most part the plant communities were dominated by perennial grasses and forbs. Trees (predominantly aspen and balsam poplar) had scattered distribution, occurring often in clumps

at the base of slopes. Shrubs (predominantly Salix spp.) also had scattered occurrence and generally low cover. Bryophytes occurred in mesic microsites, often where vascular plant cover was high, but generally had low cover. Terrestrial lichens (foliose) occurred in three stands but had low cover.

A total of 83 vascular species were found in the stands. Of these, 40 (48%) were rare, i.e. occurred in <10% of stands. Only common dandelion (Taraxacum officinale) and slender wheatgrass (Agropyron trachycaulum) were present in more than 80% of stands. In a floristic survey of abandoned minesites in the foothills, Russell (1980) listed 107 vascular species for Sterco-Coal Valley.

Species dominance varied greatly over short distances, thus making community classification difficult. Nonetheless, two variable community types were tentatively recognized, one on each of the two spoil types.

Taraxacum officinale - Potentilla norvegica community type (common dandelion-rough cinquefoil).

This community occurred on the coal dominated spoil-heaps. Total plant cover ranged from 0.05 to 50.0% ($\overline{X}$ = 9.4%) and richness from 1 to 15 species/100 m^2 ($\overline{X}$ = 4.5). Taraxacum officinale was the cover dominant and the only species present in all stands on the coal spoils. Other relatively abundant species were: Agropyron trachycaulum, Poa pratensis, Trifolium hybridum, and T. pratense. Bromus inermis, Festuca rubra, Populus tremuloides, and Sonchus uliginosus were locally prominent. The character species were: Arabis hirsuta, A. drummondii, Collomia linearis, Erysimum cheiranthoides, Galeopsis tetrahit, Potentilla norvegica, Rumex acetosella, and Viola adunca.

This community was concentrated on the Sterco minesite, where it is known there was some past reclamation effort by the Alberta Forest Service.

Unfortunately, records were not kept on the details of the reclamation, thus precluding a meaningful assessment of the methods and materials used. Several agronomic grasses and legumes were still present, although most showed signs of apparent nutrient stress (chlorosis): smooth brome (Bromus inermis, red fescue (Festuca rubra), timothy (Phleum pratense), Kentucky bluegrass (Poa pratensis), Canada bluegrass (Poa compressa), alsike clover (Trifolium hybridum), red clover (Trifolium pratense), white clover (Trifolium repens), yellow sweetclover (Melilotus officinalis) and white sweetclover (Melilotus alba). Agronomic species accounted for an average of 36.2% (range 0 to 88.5%) of total plant cover on the coal spoils.

Agropyron trachycaulum - Oxytropis deflexa community type (slender wheatgrass-reflexed loco-weed).

This community occurred on the mudstone spoils. Total plant cover ranged from 0.05 to 5.3% ($\bar{X}$ = 2.1%) and was generally lower than in the coal spoil community. Richness ranged from 1.8 to 11.6 species/100 m^2 ($\bar{X}$ = 6.5). Agropyron trachycaulum and Taraxacum officinale were the dominant species. Crepis elegans, Equisetum arvense, Hordeum jubatum, Oxytropis deflexa, Trifolium hybridum, and T. pratense were relatively abundant. The character species were: Crepis elegans, Deschampsia caespitosa, Oxytropis deflexa, Puccinellia nuttalliana, and Trisetum spicatum.

The reclamation history of this community is unknown. Several agronomic species were found, including: alsike clover, red clover, white clover, Kentucky bluegrass, Canada bluegrass, and timothy. These species accounted for an average of 15.1% (range 0.3 - 75.7%) of the total plant cover.

The two communities recognized in this study were similar physiognomically and had a number of species in common with the minesite communities described by Russell (1980) at Mountain Park. Although the floristic similarities were not high enough for the same community names to be used, several species

were abundant (or locally prominent) in both areas, including: Agropyron trachycaulum, Crepis elegans, Equisetum arvense, Festuca rubra, Oxytropis deflexa, Potentilla norvegica, and Taraxacum officinale. The stands in the present study had significantly higher total plant cover ($p < 0.05$) than those at Mountain Park, probably reflecting the fact that Sterco-Coal Valley is lower in elevation, has a milder climate, and is less wind exposed.

Plant-Edaphic Relationships

Species were arranged in five groups based on their spoil type affinities:

1. species restricted to the coal spoils;
2. species concentrated on the coal spoils, but not restricted to them;
3. species restricted to the mudstone spoils;
4. species concentrated on the mudstone spoils; and
5. species without spoil affinities (Table 2).

The last group (5) includes the more uniquitous and consistently dominate species.

Neither total plant cover nor species richness were significantly correlated with the edpahic variables when all stands were included in the calculations ($P > 0.05$). However, when just the stands on mudstone spoils were used total cover was negatively correlated with pH ($P < 0.05$). Species richness was negatively correlated with electrical conductivity ($P < 0.01$), fine earth content ($P < 0.01$), and positively correlated with sand content ($P < 0.01$). This suggests that high pH's, moderately high salinity, and/or high clay content acted to inhibit the development of a plant cover on the mudstone spoils. Surface crusting and soil erosion may also have contributed to the low cover.

No significant correlations with edaphic variables were obtained for total cover and species richness when just the stands on coal spoils were considered. However, low plant cover and richness were observed in areas

Table 2. Species cover and presence in stands on the coal spoils (N = 14) and mudstone spoils (N = 10). Only species occurring in > 10% of all stands are included.

Species	Coal Spoils Presence (%)[1]	Coal Spoils $\bar{X}$ Cover (%)	Mudstone Spoils Presence (%)[1]	Mudstone Spoils $\bar{X}$ Cover (%)
Restricted to Coal Spoils				
Galeopsis tetrahit	71	0.13	-	-
Potentilla norvegica	64	0.13	-	-
Populus tremuloides	50	0.33	-	-
Erysimum chieranthoides	50	<0.01	-	-
Rumex acetosella	43	0.02	-	-
Arabis drummondii	36	0.01	-	-
Arabis hirsuta	36	<0.01	-	-
Viola adunca	29	0.05	-	-
Bromus inermis	21	14.93	-	-
Festuca rubra	21	7.03	-	-
Stellaria longipes	21	0.07	-	-
Agropyron repens	21	0.04	-	-
Collomia linearis	21	<0.01	-	-
Concentrated on Coal Spoils				
Poa pratensis	64	0.59	20	0.02
Sonchus uliginosus	57	0.63	10	<0.01
Phleum pratense	43	0.02	20	0.02
Lepidium ramoissimum	29	<0.01	10	<0.01
Restricted to Mudstone Spoils				
Oxytropis deflexa	-	-	90	0.03
Puccinellia nuttalliana	-	-	40	0.01
Trisetum spicatum	-	-	30	0.02
Deschampsia caespitosa	-	-	30	0.02
Concentrated on Mudstone Spoils				
Hordeum jubatum	29	<0.01	90	0.13
Equisetum arvense	14	1.28	80	0.26
Crepis elegans	14	<0.01	80	0.03
Trifolium repens	7	<0.01	40	0.02
Poa alpina	7	<0.01	40	<0.01
Without Spoil Affinities				
Taraxacum officinale	100	1.33	100	0.18
Agropyron trachycaulum	86	0.42	100	0.16
Trifolium hybridum	71	0.70	70	0.07
Trifolium pratense	64	1.13	80	0.55
Fragaria virginiana	64	0.10	70	0.05
Achillea millefolium	64	0.06	80	0.01
Poa palustris	64	0.03	60	<0.01
Poa interior	50	0.02	60	0.02
Populus balsamifera	36	0.10	20	0.16
Aster ciliolatus	36	0.04	60	0.01
Poa compressa	29	0.06	50	<0.01
Gentianella amarella	29	0.01	30	<0.01
Epilobium angustifolium	14	0.20	20	<0.01
Elymus innovatus	14	<0.01	20	<0.01
Agropyron subsecundum	14	<0.01	20	<0.01

[1] percentage of stands in which a species was present.

with a surface of fine-sized coal particles (fines), and on steep, unstable slopes of loose coal materials. High surface temperatures and/or lack of suitable microsites for seed lodgement and plant establishment may explain why the coal fines were poorly vegetated. Temperatures as high as 59°C were recorded on a level, unvegetated surface of coal fines on June 29, 1976 (Barnes PRT-10 infrared thermometer).

Relationships between plant distribution and edaphic variability are commonly reported in studies of natural revegetation on mined land (see literature review in Russell 1980). In fact, few such studies were found that failed to mention the variability of the spoils and the associated variability in vegetation.

Effects of Slope Position

The sampled slopes ranged in length from 9 to 34 m, had predominantly SW, W, and NW exposures, and ranged in mid-slope angle from 28 to 41°.

The Friedman tests were highly significant ($P < 0.005$), indicating that species richness and total plant cover varied significantly with slope position. Cover and richness were highest at the slope base and lowest at the upper- and mid-slope positions (Table 3).

Species varied in their response to slope position (Table 4). Many occurred at all six slope positions while others were more restricted in distribution. Most species, however, had their highest quadrat frequency at the slope base and lowest frequency at the upper-slope and/or mid-slope positions.

The results suggest that the slope base is most favorable for natural revegetation and the upper slope and mid-slope positions are least favorable. The cause(s) of this pattern is unknown. However some possible explanations include:

Table 3. Effects of slope position on total plant cover and species richness.

Slope Position	Median Total Plant Cover (%)		Median Number Species/4m^2
Top	1.1[1]	a[2]	5.0 ab
Crest	1.1	abc	3.0 bcd
Upper-slope	0.3	c	2.0 d
Mid-slope	0.6	bc	2.5 cd
Lower-slope	1.1	ab	5.0 bc
Base	6.7		8.5 a

[1]Each median is based on a sample size of 20.

[2]Medians followed by the same letter within a column are not significantly different at the 5% confidence level.

Table 4. Species quadrat frequencies (%) at each of six major slope positions (N = 20 for each position). Species occurring in >15% of all quadrats and/or in >15% of quadrats at any one slope position are included.

Species	Top	Crest	Upper-Slope	Mid-Slope	Lower-Slope	Base
Achillea millefolium	10	15	5	5	35	55
Agropyron trachycaulum	40	25	10	35	40	75
Aster ciliolatus	20	15	0	0	5	20
Collomia linearis	0	5	5	5	5	20
Crepis elegans	35	35	40	35	30	10
Epilobium angustifolium	0	0	5	0	5	25
Equisetum arvense	50	50	45	35	50	60
Fragaria virginiana	30	25	10	5	20	40
Galeopsis tetrahit	20	20	10	15	20	20
Hordeum jubatum	25	20	20	20	20	20
Poa palustris	30	15	0	20	35	45
Populus balsamifera	20	10	0	15	10	20
Potentilla norvegica	20	20	5	5	5	0
Salix planifolia	0	0	0	5	5	20
Taraxacum officinale	75	55	45	60	75	85
Trifolium hybridum	10	10	0	5	20	60
Trifolium pratense	35	25	15	20	40	85

1. the base is more moist and less exposed to wind;

2. spoil stability is greater at the base and top;

3. fine spoil materials may accumulate at the base and lower-slope via downslope movement or wind deposition, thus improving water and nutrient holding capacity;

4. snow distribution and meltout may favor the base and lower-slope;

5. water soluble nutrients may be leached downslope;

6. seeds may accumulate downslope due to wind deposition or slope wash.

In Saskatchewan Archibold (1980) found that seed input on spoil-heaps was little influenced by slope position, but that slope wash during rain storms moved seeds downslope.

Studies made elsewhere also cite similar influence of slope position on minesite plant distribution, including Root (1976), Jonescu (1979), Errington (1975), Byrnes and Miller (1969), Hall (1957), and Molyneux (1964). Russell (1980) conducted a similar transect study at Mountain Park and obtained essentially the same results as in the present study.

Some Implications for Reclamation

1. Shrubs were not an important component of the spoil-heap vegetation. However, this may be an establishment problem which could be overcome by using containerized or bareroot seedlings. Eight species of willow (Salix) were found on the spoil-heaps (see Russell 1980), suggesting their potential for reclamation.

2. Trees had sporadic cover on the spoil-heaps but nonetheless should be considered for reclamation. The most abundant were aspen and balsam poplar. Lodgepole pine was less common than the poplars as a volunteer but was observed doing well in some reclamation test plots at Sterco and Lovett.

3. Several agronomic grasses and legumes were abundant on both spoil types and are suggested for reclamation: slender wheatgrass, alsike clover, and red clover. Red fescue, smooth brome, and Kentucky bluegrass were not widely distributed but were locally prominent.

4. Total plant cover and species distribution varied considerably with spoil properties, thus indicating the importance of materials handling in reclamation on this site. Specifically, it is recommended that the mudstone spoils be buried so as not to adversely influence the rooting zone.

5. The results of the transect study show the favorability of the lower-slope and the slope base topographic positions for revegetation. It follows that reclamation practices such as slope terracing, which increase the amount of lower-slope and base area on a slope, should improve the potential of the slope for revegetation.

ACKNOWLEDGEMENTS

I thank Dr. George H. La Roi for his encouragement and guidance during this study. Bob Richards and Lou Zivot helped with the field work. Financial support was received from the Alberta Forest Service and Alberta Fish and Wildlife Division, and is gratefully acknowledged.

LITERATURE CITED

Alberta Environment. 1982. Climate of Alberta: tables of temperature, precipitation, and sunshine. Alberta Environment, Edmonton, Alberta. 93 pp.

Alexander, F.J. 1977. Structural geology of the Luscar-Sterco Mynheer A zone, Coal Valley, Alberta. M.Sc. thesis. University of Alberta, Edmonton, Alberta. 72 pp.

Allen, J.A. and R.L. Rutherford. 1924. Geology along the Blackstone, Brazeau, and Pembina Rivers in the Foothills Belt, Alberta. Scientific and Industrial Research Council, University of Alberta, Edmonton, Alberta. Report No. 9. 48 pp.

Archibold, O.W. 1980. Seed input as a factor in the regeneration of strip-mine wastes in Saskatchewan. Can. J. Bot. 58: 1490-1495.

Byrnes, W.R., and J.H. Miller. 1969. Natural revegetation and cast overburden properties of surface-mined coal lands in southern Indiana. In Ecology and reclamation of devastated land. Vol. I. Edited by R.J. Hutnik and G. Davis. Gordon and Breach, New York. pp. 285-306.

Daniel, W.W. 1978. Applied nonparametric statistics. Houghton Mifflin Company, Boston, Massachusetts. 503 pp.

Errington, J.C. 1975. Natural revegetation of disturbed sites in British Columbia. Ph.D. Thesis, University of British Columbia, Vancouver, British Columbia 145 pp.

Hall, I.G. 1957. The ecology of disused pit heaps in England. J. Ecol. 45: 689-720.

Hardy Associates (1978) Ltd. 1980. Final report vegetation section, environmental impact assessment, Foothills Project. Prepared for Gulf Canada Resources Inc. 25 pp.

Jonescu, M.E. 1979. Natural revegetation of strip-mined land in the lignite coalfields of southeastern Saskatchewan. In Ecology and coal resource development. Edited by M.K. Wali. Pergamon Press, New York. pp. 592-608.

Lake, D.W. 1967. The historical goegraphy of the Coal Branch. M.A. Thesis, Dep. Geography, Univ. Alberta, Edmonton, Alberta 170 pp.

Lesko, G.L. and J.D. Lindsay. 1973. Forest/soil relationships and management considerations in a portion of the Chip Lake map area, Alberta. Alberta Research, Edmonton, Alberta. Report 73-1. 66 pp.

Molyneux, J.K. 1963. Some ecological aspects of colliery waste heaps around Wigan, South Lancashire. J. Ecol. 51: 315-321.

Mueller-Dombois, D. and H. Ellenberg. 1974. Aims and methods of vegetation ecology. John Wiley and Sons, New York. 547 pp.

Root, J.D. 1976. Physical environment of an abandoned strip mine near Cadomin, Alberta. University of Alberta, Alberta Research Council, Edmonton, Alberta. Bulletin No. 34. 33 pp.

Russell, W.B. 1980. The vascular flora and natural vegetation of abandoned coal-mined land, Rocky Mountain Foothills, Alberta. M.Sc. Thesis, Dep. Botany, University of Alberta, Edmonton, Alberta. 96 pp.

Schumacher, A.E.A., R. Hermesh, and A.L. Bedwany. 1977. Coal mine spoils and their revegetation patterns in central Alberta. In Proceedings of the Second Annual General Meeting of the Canadian Land Reclamation Association, Edmonton, Alberta, August 17-20, 1977. The Canadian Land Reclamation Association, Guelph, Ontario Paper No. 5. 20 pp.

Sims, H.P., and C.B. Powter. 1982. Land surface reclamation: an International Bibliography. Volumes 1 and 2. Alberta Department of Environment, Research Secretariat, Edmonton, Alberta. 292 pp.

Sørensen, T. 1948. A method of establishing groups of equal amplitude in plant sociology based on similarity of species content. Det Kong. Danske Vidensk. Selsk. Biol. Skr. (Copenhagen) 5(4): 1-34.

Strong, W.L. and K.R. Leggat. 1981. Ecoregions of Alberta. Resource Evaluation and Planning Division. Alberta Energy and Natural Resources, Edmonton, Alberta. 64 pp.

ROLE OF TOPSOIL, FERTILIZERS AND COMPANION CROPS IN REVEGETATION OF TWO SEVERE SITES IN THE ALBERTA FOOTHILLS AND MOUNTAINS[1]

S.K. Takyi

Alberta Forest Service

Department of Energy and Natural Resources

Edmonton

INTRODUCTION

The influence of fertilizer or topsoil in revegetation of a drastically-disturbed site has most often rated high as a factor for reclamation success in field trials and under operational reclamation situations in Alberta's Rocky mountains and Foothills region. In exposed high-elevation environments these two factors are as important as climatic factors in limiting plant growth and hence in cover establishment. The role of fertilizers is in the improvement of the fertility of a site; that of topsoil includes improvement in fertility as well as in the physical properties of the soil which are important for good growth of plants. In the harsh environments under discussion, topsoiling and fertilization play significant roles in improving the microsite to increase the chances of revegetation success.

---

[1]This paper has been published as Energy and Natural Resources Technical Report Number: T/67.

In field reclamation trails, grass-legume mixture ground covers have shown responses to fertilizers. Often, if the objective was an initial site stabilization to encourage the ingress of native vegetation or to allow for the later successful establishment of woody species, the problem has been in the management of the dense plant cover due to fertilizers.

Our experience in Alberta's alpine and subalpine zone generally shows that native grasses seeded on disturbed sites do not develop a ground cover as fast as cultivated grasses and legumes. In a situation whereby a rapid, erosion-controlling plant cover is the primary objective, and where native grasses are the primary plant cover desired for some specified reasons, seeding the faster growing cultivated species as companion crops appears the best choice in achieving both objectives.

The trials reported have involved other individuals who are still employed by the Forest Service or worked with the Service sometime between 1978 and now. This paper is therefore a summary of portions of the trials, with the objectives of: (a) evaluating the effects of fertilizers on the establishment and growth of native grass seed mixtures and cultivated grass-legume seed mixtures, (b) comparing the difference in plant cover establishment between overburden or mine spoil, and the same two waste materials topdressed with mineral soils, and (c) evaluating the effects of companion crops on native grass seed mixtures in plant cover establishment.

EXPERIMENTAL SITE

Six of the eight trials discussed in this paper are located on an abandoned mine near Cadomin in west-central Alberta, and two are located at Adanac in the south-western part of the province near Blairmore. At each site, one set of the trial was located on the raw overburden or spoil and the other on overburden or spoil which was topdressed with mineral soil to an average depth of 20 cm.

The two locations were abandoned minesites, and although far from each other, experience similar climatic and environmental conditions. The Cadomin site is described elsewhere in these proceedings by the same author. Adanac is an abandoned strip mine on Hastings Ridge in the Front Ranges 12 km south of Blairmore. The mine is believed to have been abandoned in the early 1950's. The area is classified in the subalpine forest region, and the site is at an elevation of 1 895 m. Site conditions in terms of precipitation, exposure and windspeeds are similar to those at Cadomin but chinooks are more frequent and last longer. The temperatures at Adanac are slightly higher than at Cadomin, but extremes are similar.

REHABILITATION METHODS

A. Fertilizer Treatments

The trials were laid out at Cadomin in June 1978, on overburden and on spoil. They were done separately on the raw materials and on the raw materials topdressed with mineral soil.

1. Cultivated Seed Mixture Trail

The trials were laid out on the raw spoil and on the same spoil which was topdressed with mineral soil to an average depth of 20 cm. They were laid out as a randomized block design in three replications and consisted of five fertilizer rate and four seeding rate treatments. The seed mixture was composed of creeping red fescue (40% by weight), white clover (12%), Timothy (24%), and Canada bluegrass (24%). The seed and fertilizer were both broadcast and raked into the soil.

2. Native Grass Mixture Trial

The trials were laid out on the raw overburden and on the same overburden topdressed with mineral soil to an average depth of 20 cm. Both were laid out in a randomized complete block design with three replications. Three fertilizer rates were tested along with two other factors, seeding rate and companion crops. The native grass seeding mixture was composed of equal numbers of seeds of Agropyron trachycaulum (69% by weight), Festuca saximontana (15%), Poa interior (8%) and Trisetum spicatum (8%).

B. Companion Crop Treatments

The trials were laid out on overburden in two separate studies in 1978 and 1979 at Cadomin, and in a single study in 1979 at Adanac. The trials were repeated at both locations on overburden topdressed with mineral soil. Native grass seed mixes were used in all six trials.

The 1978 trials at Cadomin had the following companion crop treatments: barley (20 kg/ha); red clover (3 kg/ha); cultivated species mix

(creeping red fescue, 40% by weight; white clover, 12%; timothy, 24%; Canada bluegrass, 24%; seeded at 15 kg/ha); and a control. The rest of the treatments and other details of the trials are the same as the fertilizer treatments for native grass mixture trials described above.

The trials laid out in 1979 in both locations were designed to evaluate five companion crops and four native grass seed mixtures. The treatments were replicated three times in a randomized complete block design. Companion crop treatments applied at 5 kg/ha were: meadow foxtail; Timothy and white clover; creeping red fescue and alsike clover; perennial rye grass; and a control. The plots were raked before and after hand seeding and fertilizing with urea, 10-30-10 and potassium chloride to provide 80 kg N, 60 kg P and 60 kg K/ha.

RESULTS AND DISCUSSIONS

Overburden and Spoil Properties

Soil analyses results (summarized in Tables 1 and 2) show that the spoil, overburdens or mineral soils used for topdressing cannot be considered fertile materials for optimum plant growth. This implies that responses to fertilizers are expected to be high, assuming the fertilizer nutrients can be retained without being mostly leached out of the highly porous overburden and spoil. The overburden and the spoil at Cadomin are alkaline, and the overburden at Adanac is very acid in reaction, so that they can significantly affect the growth of sensitive plant species.

TABLE 1

SOME PROPERTIES OF THE SPOIL, OVERBURDEN AND MINERAL SOIL USED FOR TOPDRESSING AT CADOMIN*

	CULTIVATED SPECIES		NATIVE GRASS SPECIES	
	SPOIL	MINERAL SOIL	OVERBURDEN	MINERAL SOIL
pH	8.8	6.9	8.9	6.5
Ec (mS/cm)	0.3	0.1	0.3	0.1
AVAIL. NUTRIENTS (ppm)				
NH_4-N	5.6	4.5	3.7	4.1
NO_3-N	0	1	0	0
P	0	10	0	12
K	186	214	235	219
TOTAL N (%)	0.13	0.07	0.03	0.07
T.E.C. (me/100g)	6.6	13.2	6.4	12.7

* STUDIES STARTED IN 1978

TABLE 2

SOME PROPERTIES OF THE OVERBURDENS AND MINERAL SOILS USED FOR TOPDRESSING*

	CADOMIN		ADANAC	
	OVERBURDEN	MINERAL SOIL	OVERBURDEN	MINERAL SOIL
pH	8.4	7.1	4.6	6.4
Ec (mS/cm)	0.2	0.2	0.2	0.2
AVAIL. NUTRIENTS (ppm)				
NH_4-N	1.9	2.3	7.2	8.9
NO_3-N	1	1	0	3
P	1	2	19	11
K	89	71	43	209
TOTAL N (%)	0.06	0.08	0.27	0.27
T.E.C. (me/100g)	9.9	15.4	13.9	27.7

* (STUDIES STARTED IN 1979)

The high total nitrogen level in the spoil is attributable to the high total level of the element in the coal in the spoil (see paper by the same author elsewhere in these proceedings). The overburdens at the two locations are very similar in their physical characteristics; the characteristics of the overburden and those for the spoil are discussed by the same author in another paper in these proceedings.

Fertilizer Effects

Cultivated Grass-Legume Cover

Effects of fertilizers on the cultivated grass-legume mixture on the percentage of plant cover are shown in Figure 1. Dry matter yields are shown in Figure 2. Generally, both percentage of cover and dry matter yields increased as the rate of fertilizer application increased; the trends were still maintained even after annual fertilization was stopped. Both percentage of plant cover and dry matter production (shown in Figures 3 and 4) declined in 1982 as a result of the stoppage of annual fertilization of the fertilized treatments and to a more marked degree in 1983. (Percentage of plant cover in this context refers to the above-ground living plant parts. This tends to underestimate percentage of cover because accumulated thatch is essentially ignored.) Although percentage of cover in the first two seasons was generally greater on the raw spoil than on topdressed spoil, dry matter production was lower on the raw spoil. The odd relation between dry matter production and percentage of

Figure 1: FERTILIZER EFFECTS ON PLANT COVER FOLLOWING FOUR SEASONS (1981) OF FERTILIZATION, AND TWO SEASONS (1983) AFTER FERTILIZERS WERE WITHDRAWN.

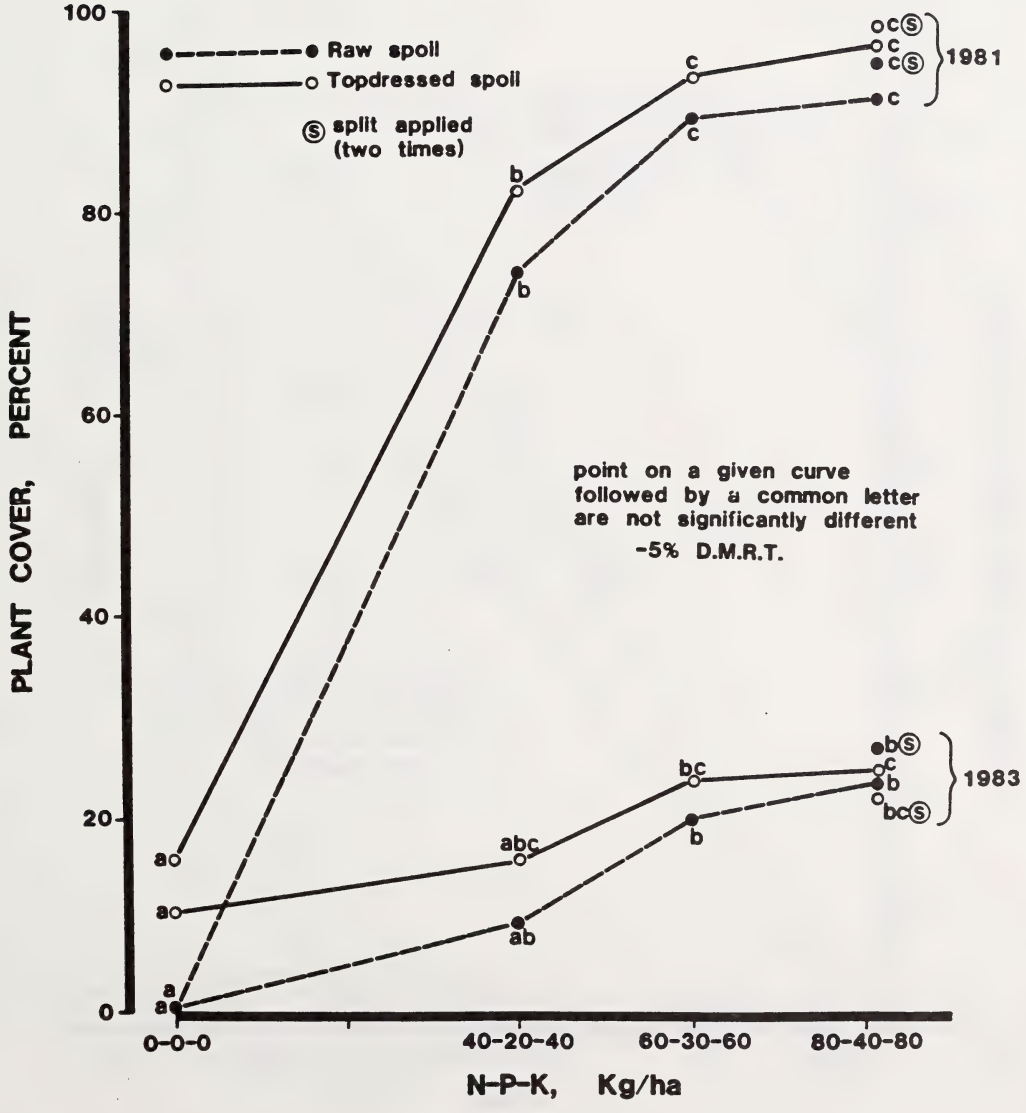


Figure 2: DRY MATTER YIELDS FOLLOWING FOUR SEASONS OF FERTILIZATION AFTER SEEDING TO 1981 AND TWO SEASONS (1983) AFTER FERTILIZERS WITHDRAWN.

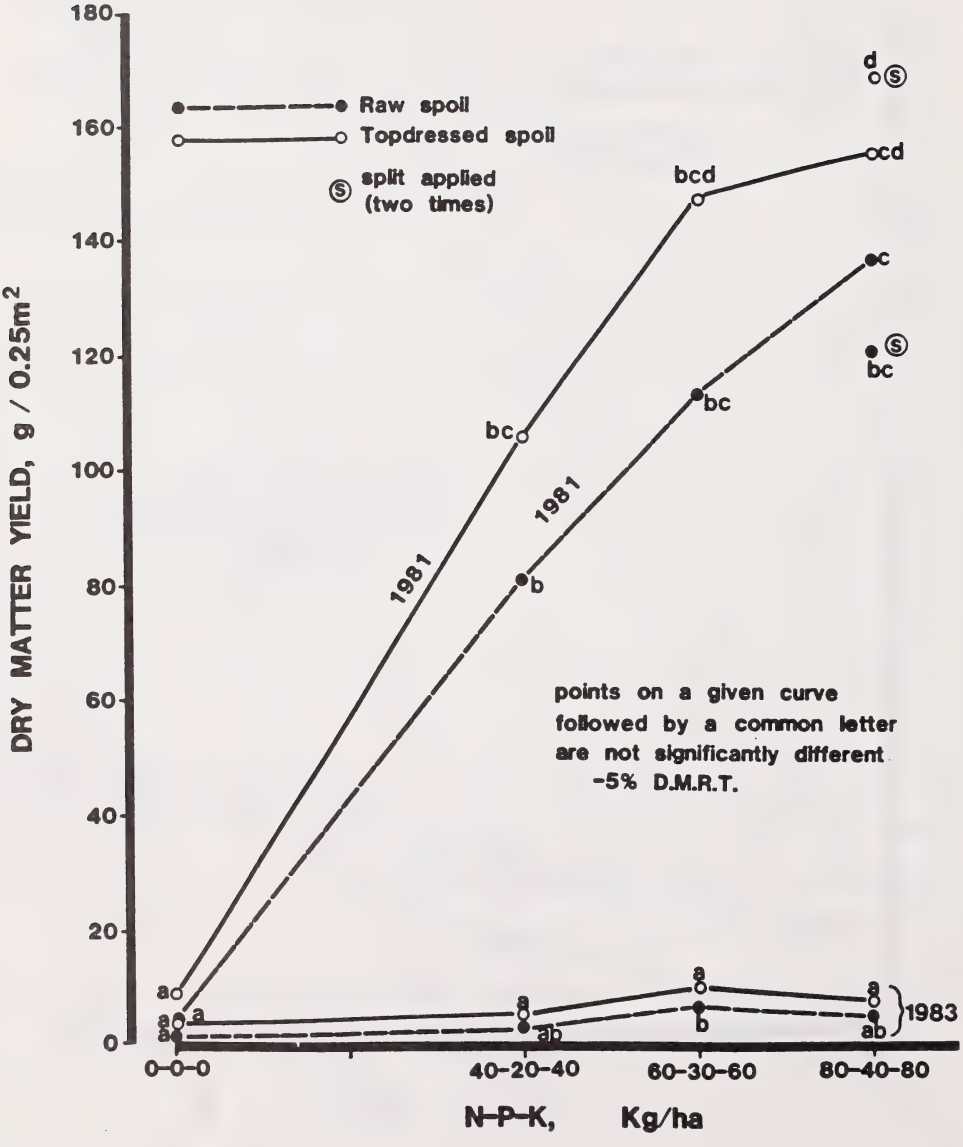


Figure 3: CHANGES IN PLANT COVER BETWEEN SEEDING AND 1983 (TWO SEASONS AFTER FERTILIZERS WERE WITHDRAWN - FOR 60N-30P-60K Kg/ha.)

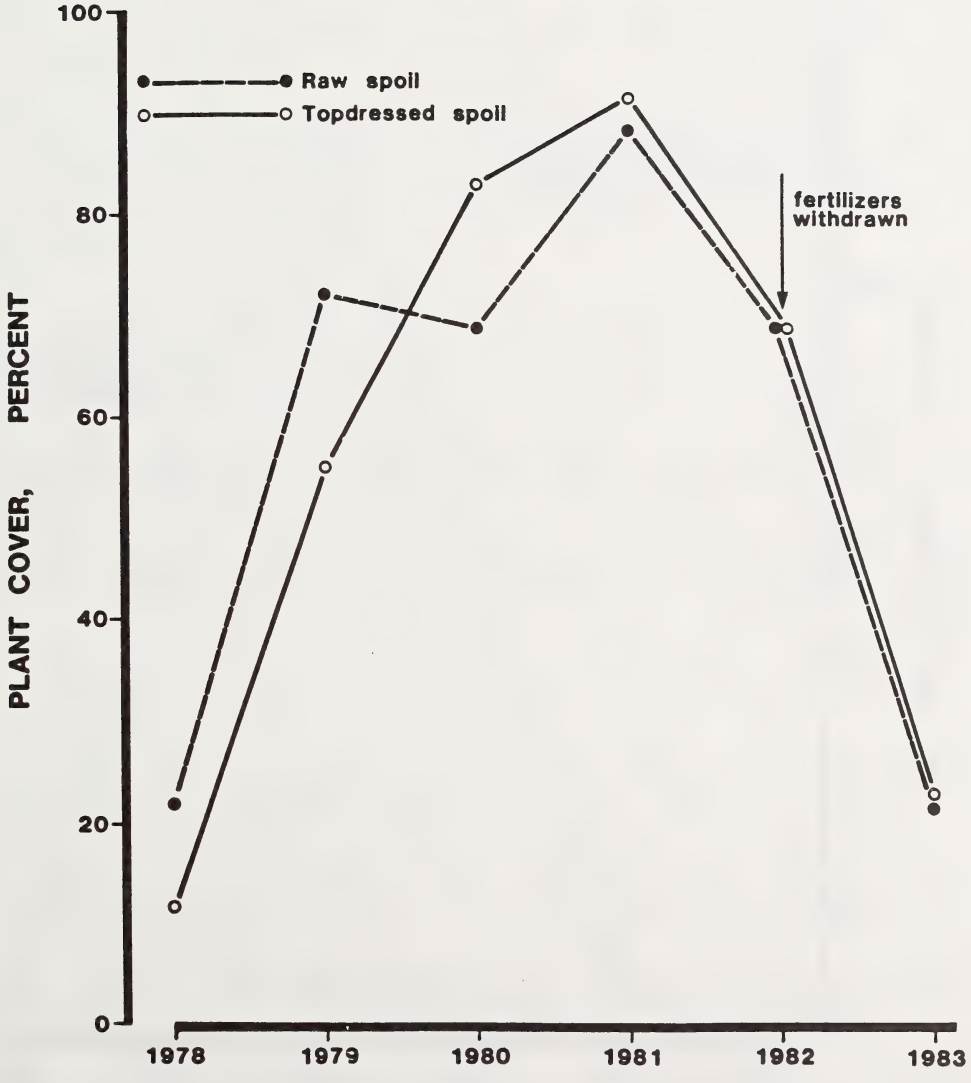
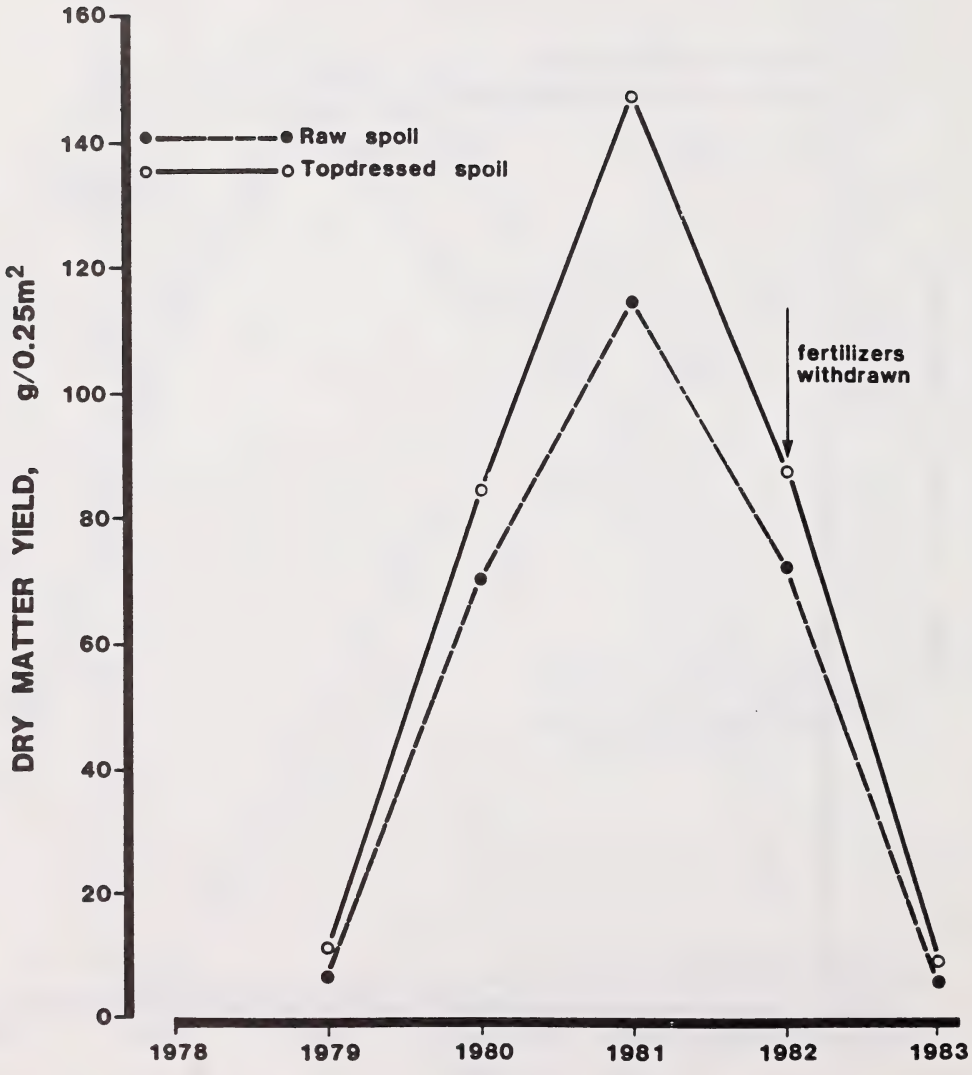


Figure 4: CHANGES IN DRY MATTER YIELDS BETWEEN SEEDING AND 1983 (TWO SEASONS AFTER FERTILIZERS WERE WITHDRAWN - FOR 60N-30P-60K Kg/ha.)



cover on the spoil suggests that the grasses and legumes assumed different growth forms (plant shape and height) on the spoil than on the topdressing material in the early stages of growth. Fertilization resulted in a considerable increase in the number of flowering tillers, especially with topdressing (Figure 5). This indicates that with the production of viable seeds the species in the seeded mix could more readily reseed themselves and increase the chances of revegetation success in subsequent years. Figure 6 indicates that by fertilizing or by topdressing there is a greater chance that all species in the seeded mix in a given a given area will survive and thus achieve a better species balance in the plant cover.

Native Grass Cover

Percentage of plant cover in the native grass mix was generally low in the first two growing seasons but by the fourth season (1981) cover had increased considerably, especially in the fertilized plots (Figure 7). Topdressing resulted in a much higher percentage of ground cover, especially if carried out in conjunction with fertilization. On the unfertilized raw overburden, the little plant cover developed in the first season had completely died out by the fourth season; on the unfertilized topdressed overburden, however, cover persisted and improved somewhat with time. Dry matter production levels in the fourth season (Figure 8) corresponded closely with the levels of percentage of plant cover. Table 3 shows the presence, expressed as frequency in percent of the seeded individual species in randomly selected areas

Figure 5: FERTILIZER INFLUENCE ON FLOWERING TILLER PRODUCTION AT THE END OF THE SECOND GROWING SEASON (1979)

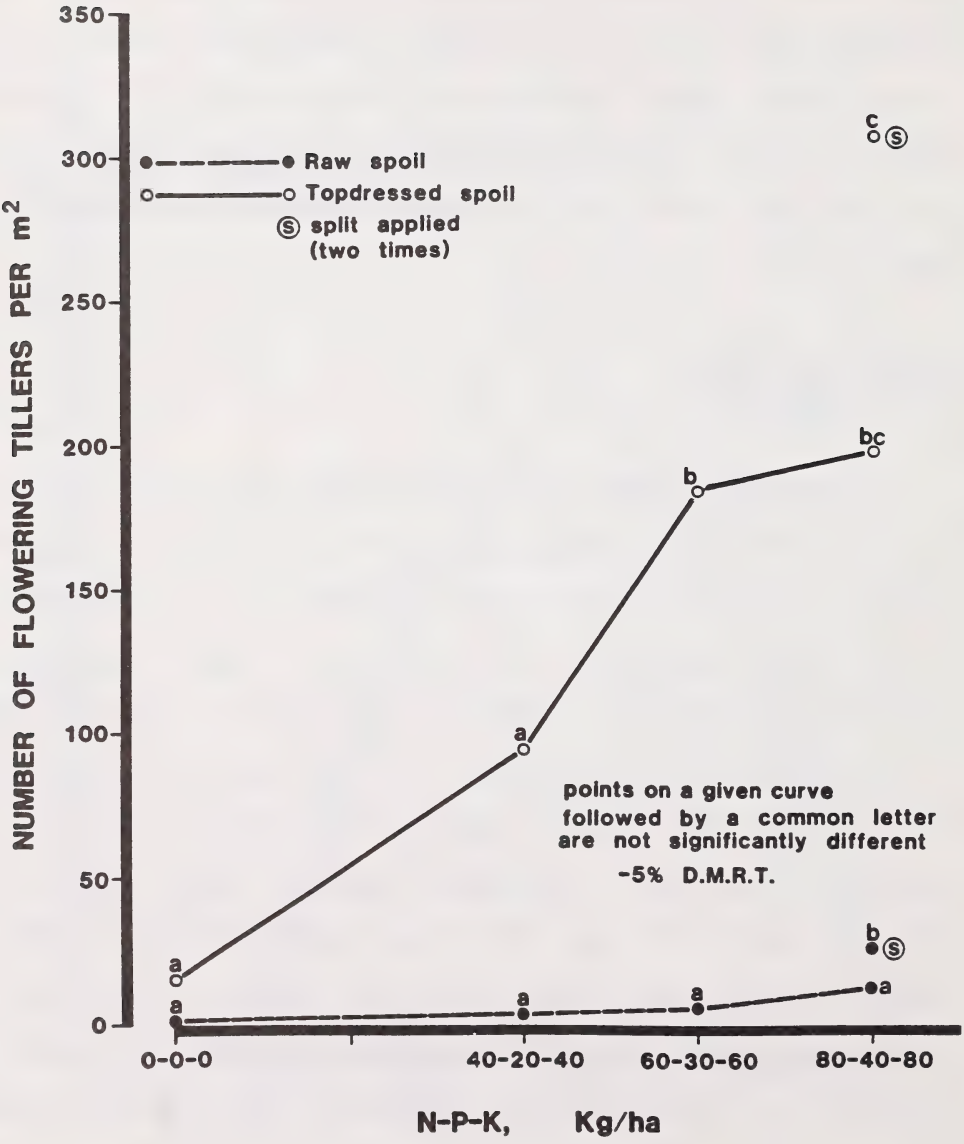


Figure 6: FERTILIZER INFLUENCE ON THE PRESENCE OF PLANTS OF ALL SEEDED SPECIES IN A GIVEN AREA (EXPRESSED AS A FREQUENCY PERCENT) AT THE END OF THE SECOND GROWING SEASON (1979) -60 Kg/ha SEEDING RATE

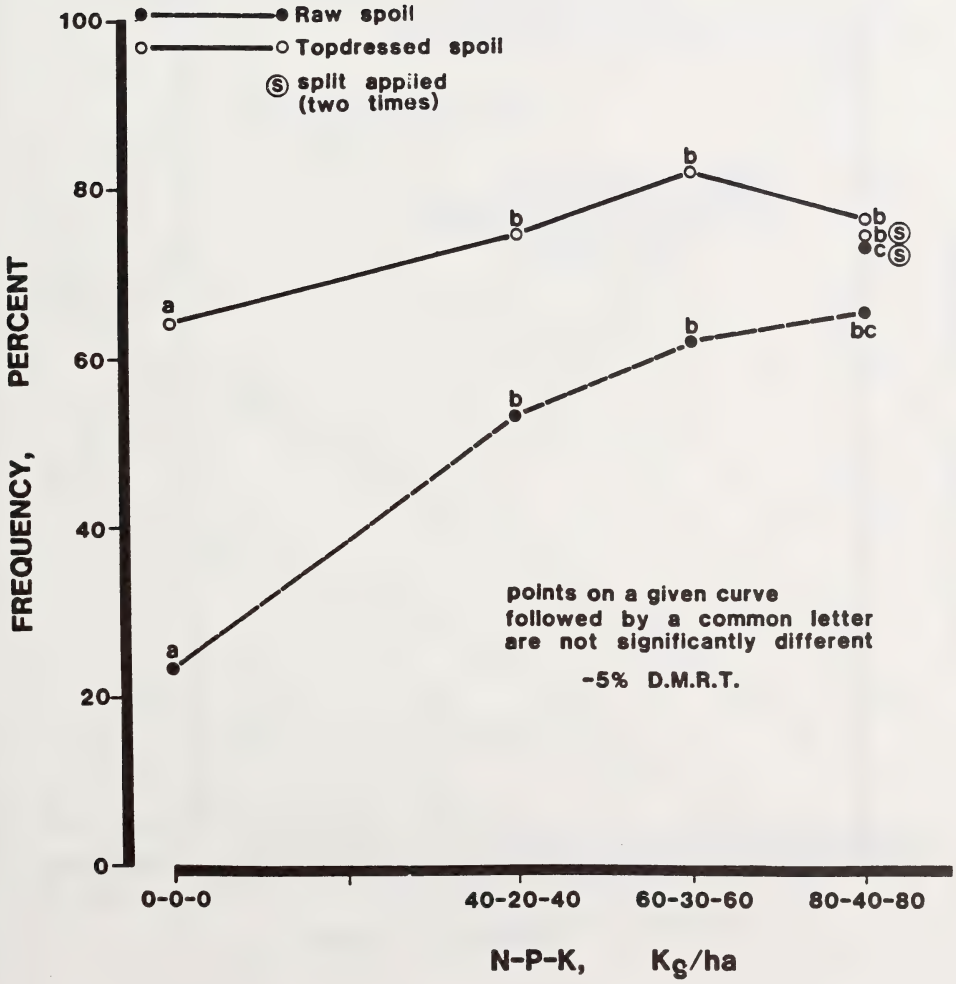


Figure 7: FERTILIZER EFFECTS ON PLANT COVER IN THE SECOND (1979) AND FOURTH (1981) SEASONS AFTER SEEDING NATIVE GRASS MIX - CADOMIN.

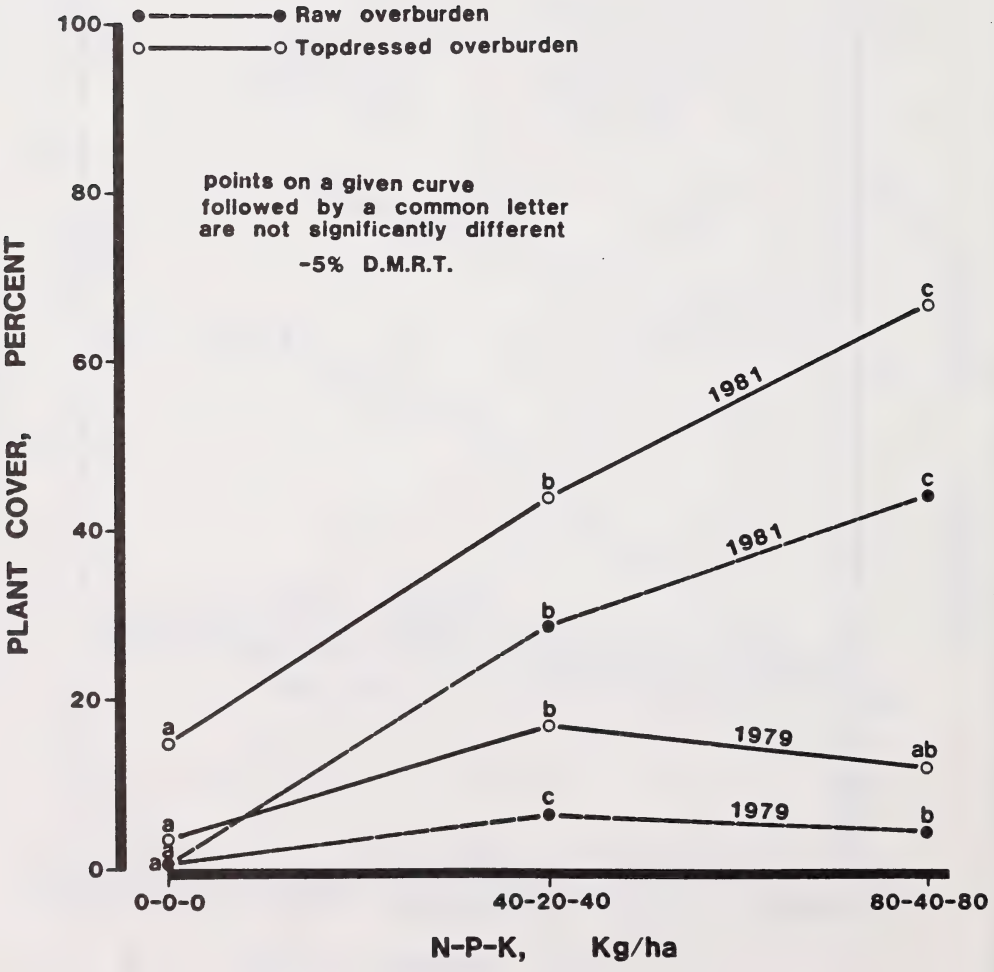


Figure 8: FERTILIZER EFFECTS ON DRY MATTER YIELDS PER PLOT IN THE FOURTH SEASON (1979) AFTER SEEDING THE NATIVE GRASS MIX - CADOMIN

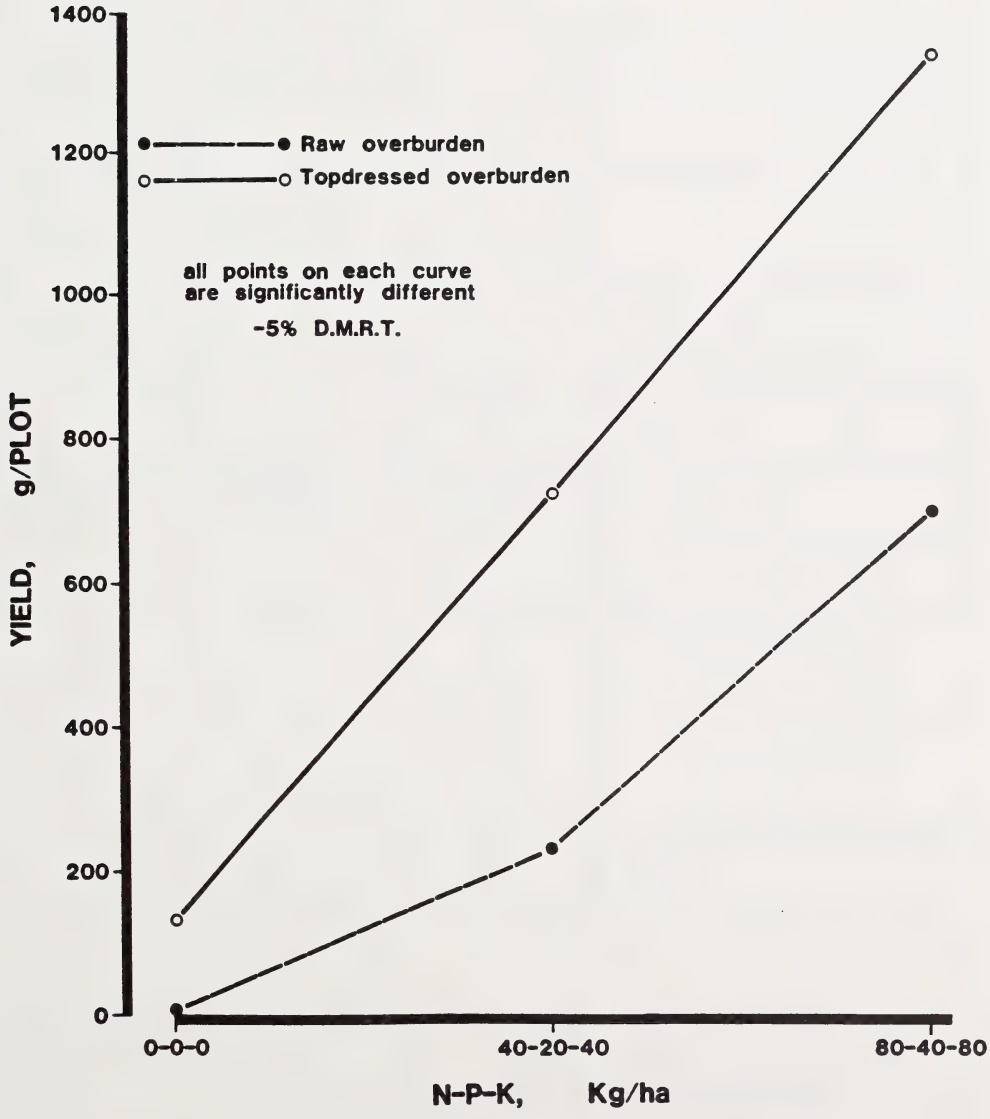


TABLE 3

FERTILIZER INFLUENCE ON THE MEAN SPECIES FREQUENCY (PERCENT) IN THE SECOND SEASON OF GROWTH OF THE NATIVE GRASS MIX* (1978 CADOMIN TRIAL)

	0-0-0	40-20-40	80-40-80
Raw overburden			
S_1 Agropyron trachycaulum	0	48	60
S_2 Festuca saximontana	27	23	31
S_3 Poa interior	0	8	10
S_4 Trisetum spicatum	0	0	2
S_5 (S_1 and S_4)**	0	2	13
Mean	5	16	23
	0-0-0	40-20-40	80-40-80
Topdressed overburden			
S_1 Agropyron trachycaulum	29	13	46
S_2 Festuca saximontana	31	8	25
S_3 Poa interior	23	4	21
S_4 Trisetum spicatum	2	0	8
S_5 (S_1 and S_4)**	6	0	2
Mean	18	5	20

* Treatment without companion crops - 1000 SEEDS m^{-2} seeding rate.

** Plants in this category were either S_1 or S_4 the two species could not be differentiated.

within the plots in the second season of growth. The results illustrate the advantage of fertilizers in achieving a more balanced species diversity on the raw overburden and clearly identifies Festuca saximontana as the species most likely to persist on sites which are very low in inherent fertility. (By the fourth season, 1981, all the plants in the unfertilized overburden plots had died.) Topdressing with a mineral soil appeared to be as effective as fertilizing the raw overburden in improving the distribution of the plants of the different species. Fertilizing the topdressed overburden did not appear to provide any advantage in the distribution of the species.

Generally, high fertilization of grass-legume mixtures results in diminished diversity in the species in the plant cover. For the conditions on the severe sites of the trials, however, fertilization of the raw overburden or spoil dramatically improved the diversity of the species in both the native grass mix and cultivated grass-legume mix.

One of the main reasons for the apparent preference for native grasses in revegetation is the expected low fertility demands on the soil. While the fertility demands may be low, the results of the fertilization trials indicate that native grasses, just as much as cultivated grasses, require certain minimum seedbed conditions, of which fertility is a very important component. Although both the native grasses and cultivated grasses and legumes seeded as companion crops in the unfertilized raw overburden plots germinated, nearly all plants which germinated in the first season eventually died. With the spreading of a mineral soil, which was also low in inherent fertility, over the overburden, some plant cover and dry matter production were achieved in the native grasses. Table 1

shows the mineral soil to be better than the raw overburden only in available P, total N, and total exchange capacity, and to have a more favorable reaction than the overburden. The increase in cover and production achieved by simply topdressing, or by applying 40 kg N, 20 kg P and 40 kg K/ha, confirms that at least on severe mine overburdens which are also low in fertility some fertilization is necessary to achieve a native grass cover.

Companion Crop Effect

The influence of companion crop treatments on the establishment and growth of native grass mixtures in high-elevation harsh environments is summarized in Figures 9 and 10, and in Table 4. Figures 9 and 10 show the results of the trials established at Cadomin in 1978 with one native grass mixture, and Table 4 shows the means for the 1979 trials with four different native grass mixtures at Cadomin and Adanac. In the 1978 trials, the results, because of the companion crops on the overburden, show no advantage in percentage of plant cover or dry matter production up to the end of the fourth growing season. The only advantage to companion crop treatment on the topdressed trial occurred in the fourth season, and this was due primarily to the role played by the cultivated perennial grasses and legumes which still persisted. The red clover in the other companion crop treatment had essentially died out.

Results of the trials which were established in 1979 (Table 4) also showed no significant advantage in percentage of plant cover due to companion crops by the end of the 1980 growing season at Adanac and

Figure 9: COMPANION CROP EFFECTS ON PLANT COVER IN THE SECOND (1979) AND FOURTH (1981) SEASONS AFTER SEEDING A NATIVE GRASS MIX - CADOMIN.

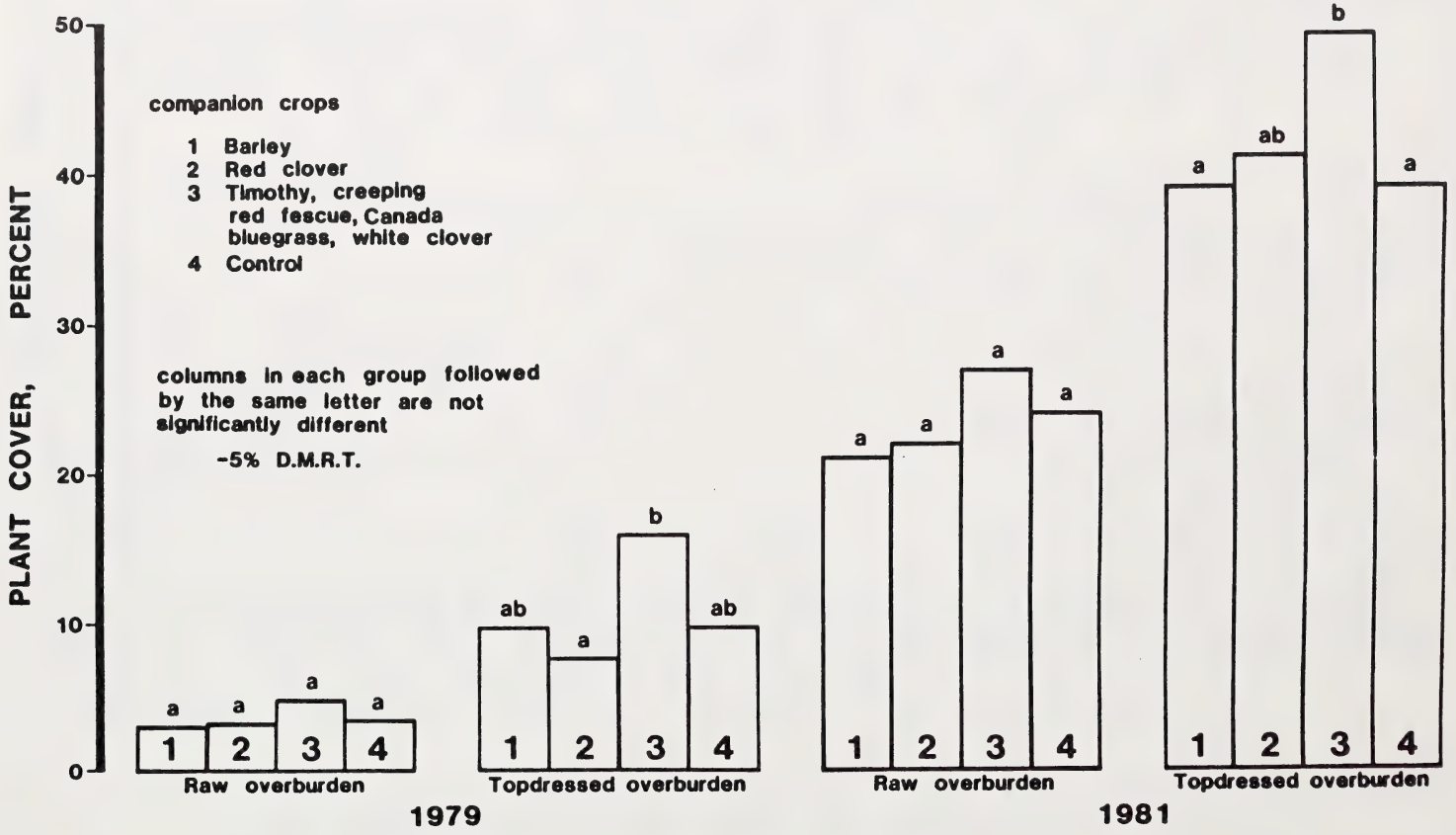


Figure 10: COMPANION CROP EFFECTS ON DRY MATTER YIELDS IN THE FOURTH SEASON (1981) AFTER SEEDING A NATIVE GRASS MIX - CADOMIN.

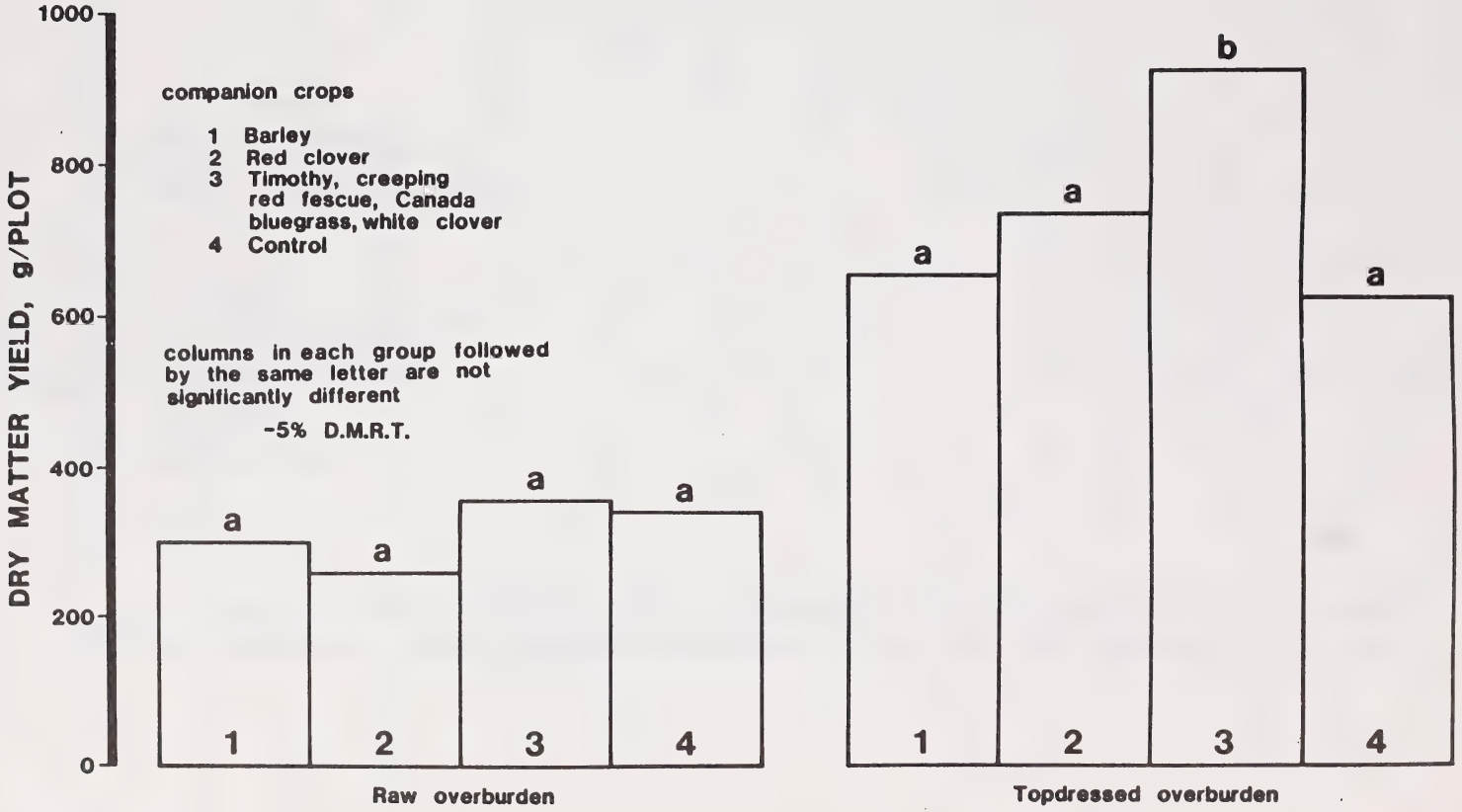


TABLE 4

MEAN INFLUENCE OF CULTIVATED COMPANION CROPS ON PERCENT PLANT COVER PRODUCED IN FOUR DIFFERENT NATIVE GRASS MIXTURES* AT THE END OF THE 1980 GROWING SEASON (SEEDED IN 1979) — After Tomm and Russell, 1981.

	COMPANION CROPS**				
	MF	T + WC	CRF + AC	PR	C
CADOMIN					
Raw overburden	9.2	13.1	12.4	14.6	11.6
Topdressed overburden	28.7	24.5	24.0	23.5	19.0
ADANAC					
Raw overburden	33.7	35.7	30.0	30.3	25.2
Topdressed overburden	36.3	27.0	22.8	24.0	20.2

* Mean of 4 native grass seed mixtures in 3 replications
Companion crop treatments differences in a given row are not significant

** MF = meadow foxtail; T + WC = Timothy and white clover;
CRF + AC = creeping red fescue and alsike clover; PR = perennial ryegrass; C = control.

Cadomin. The controls, however, generally gave lower percentage of cover as compared with the companion crop treatments. The reason for the lack of significance in the companion crop effect on cover is that in the early stages of plant cover establishment any competitive effects of the cultivated grasses and legumes on the native grasses are minimal. Results of the 1978 trials at Cadomin suggest that competitive dominance of the native grasses is possible in later stages of cover development and that some companions crops significantly influence cover by the native grasses. The trials clearly show, however, that in the first few seasons of growth companion crops offer no significant advantage in cover establishment with native grass mixtures. In general, production was greater with topdressing as compared with no topdressing; the lower plant cover with topdressing at Adanac is attributable to the higher seed and soil losses following seeding caused by wind erosion, as compared with the raw overburden on which losses were estimated to have been minimal.

The influence of the companion crops on the relative presence and distribution (expressed as percent frequency) of the native grass plants in the plots are given in Table 5 for the 1978 trials. Barley and red clover as companion crops had died out, and the grass-legume mixture still persisted by the end of the second growing season; however, the frequency of the native grasses in the grass-legume companion crop did not differ much from that of the control or any of the other treatments. The comparatively high percentage of native grasses, even with the highly competitive cultivated companion grasses and legume mix as

TABLE 5

MEAN COMPANION CROP INFLUENCE ON INDIVIDUAL NATIVE GRASS SPECIES FREQUENCY (PERCENT) AT THE END OF THE SECOND GROWING SEASON (1979) AT CADOMIN

	BARLEY	RED CLOVER	MIX *	CONTROL	MEAN
Raw overburden					
S_1 Agropyron trachycaulum	35	38	38	35	37
S_2 Festuca saximontana	38	41	39	40	40
S_3 Poa interior	6	10	7	8	8
S_4 Trisetum spicatum	1	0	0	1	1
S_5 (S_1 and S_4) **	5	3	3	6	4
Mean	21	23	22	23	22
(Companion Crop)	(0)	(0)	(33)		
Topdressed overburden					
S_1 Agropyron trachycaulum	50	51	51	49	50
S_2 Festuca saximontana	41	42	39	37	40
S_3 Poa interior	34	30	27	30	30
S_4 Trisetum spicatum	8	7	6	9	8
S_5 (S_1 and S_4) **	6	5	5	6	6
Mean	35	34	32	33	34
(Companion Crop)	(0)	(1)	(88)		

* Timothy, creeping red fescue, Canada bluegrass and white clover.

** Plants in this category were either S_1 or S_4 the two species could not be differentiated.

compared with the other treatments, again may suggest that, at least in the early stages of growth, native grasses are able to compete favorably with cultivated species.

CONCLUSIONS

The trials discussed in this paper have identified the need for a minimum soil fertility requirement for grasses in the revegetation and rehabilitation of severe land disturbances in alpine and subalpine environments. This minimum requirement applies equally to native grass mixtures and cultivated grass-legume mixtures grown on unamended mine spoil or overburdens inherently low in the essential plant nutrients.

In these trials, plant cover establishment failed in both cultivated and native grass mixtures on the raw overburden or spoil. Topdressing resulted in some improvement in cover establishment and biomass production, and fertilizers always assured cover establishment success. Fertilization increased the number of flower-bearing tillers in the cultivated grasses and thus improved the chances of seed production for the eventual filling in of the bare areas of the plots. Fertilization also improved the chances of achieving a mixed-species plant cover, as opposed to a poor cover of one species which may be fairly tolerant of low soil fertility. This observation appears to contradict the widely accepted fact that high fertilization of grass-legume mixtures results in diminished diversity of the species in the plant cover. In general, topdressing with a mineral soil may be considered an alternative to fertilization if the inherent native fertility meets a critical requirement.

Native grasses apparently have a lower soil fertility requirement than cultivated species. The results of these trials show, at least for the severe environments of these trials, that if cultivated grasses do not grow because of poor soil fertility, we should not expect the native grasses to grow any better.

Native grasses have been expected to be better plants for revegetation of alpine and subalpine areas than introduced species, because native plants are known to be better adapted climatically and therefore more capable of surviving in the severe sites. Experience, however, shows that plant cover in the first season of growth in alpine and subalpine regions is at best minimal in most cases with native grasses. In situations where site stabilization in the shortest possible time is the primary objective, native grass usefulness may be greatly diminished. For this reason, the use of faster-growing cultivated species as companion crops to the native grasses strikes an appeal. Results of the six trials, three on overburden and three on topdressed overburden, generally gave the same percentages of plant cover levels and dry matter production with companion crops as with the control on the raw overburden. In the second season of growth on the topdressed overburden, companion crop treatments gave generally higher, but not significantly higher, percentage of plant cover than the control; by the fourth season of the trials started in 1978 only the cultivated grass-legume companion crop mixture had given a significantly higher dry matter production than the control.

In general, on these severe sites in the alpine and subalpine regions, it could be concluded that companion crops made up of cultivat-

ed grasses and/or legumes proved to be of little benefit to the successful establishment of native grass cover in the early stages of growth, whereas normally the fast-growing cultivated species establish more rapidly to stabilize the ground surface. The companion crops did not appear to have influenced the relative presence and distribution of the native grasses in the established plant cover at the end of the second growing season.

REFERENCES

Russell, W.B. and Takyi, S.K. 1979. The Cadomin Reclamation Research Project First Year Results (1978). ENR Report No. 121. Alberta Department of Energy and Natural Resources, Alberta Forest Service, Edmonton.

Takyi, S.K. 1984. Plant Cover Establishment Methods on a Severe Rocky Mountain Foothills Site. ENR Report No. T/66. Alberta Department of Energy and Natural Resources, Alberta Forest Service, Edmonton.

Takyi, S.K. and Russell, W.B. 1980. the Cadomin Reclamation Research Project Second Year Results (1979). ENR Report No. 155. Alberta Department of Energy and Natural Resources, Alberta Forest Service, Edmonton.

Tomm, H.O. and Russell, W.B. 1981. Native Grass and Cultivated Grass- Legume Seed Mixture Trials on Subalpine Coal-Mined Disturbances in Alberta. A Progress Report for 1980. ENR Report No. T/21-80 Alberta Department of Energy and Natural Resources, Alberta Forest Service, Edmonton.

Establishment and Maintenance of Plant Cover on Disturbances In The National Parks

Gail Harrison

Parks Canada

ABSTRACT

This Paper reviews the types of Disturbances and Reclamation Objectives common in the National Parks. Many revegetation methods have been assessed over the years. These are discussed and successful techniques identified through Research and Practice are highlighted.

Canada's national park system has an established program objective.

"to protect for all time representative natural areas of Canadian significance in a system of national parks, and to encourage public understanding, appreciation and enjoyment of this natural heritage so as to leave it unimpaired for future generations" (Parks Canada, 1979). Within this mandate, a dichotomy arises - to preserve ecological integrity while providing opportunities which encourage understanding and enjoyment of the resources.

Visitor opportunities are provided through facilities such as hiking, trails, ski areas, visitor centers and secondary roads. In addition many of the western region parks are dissected by transportation corridors, projects associated with major terrain disturbance. These include the Trans Canada Highway (TCH) twinning in Banff, Canadian Pacific Railway (CPR) mainline improvements in Banff and Glacier, and Canadian National Railway (CNR) line twinning in Jasper.

Rehabilitation is an integral component of minimizing the conflict which arises between these activities and the need to protect natural resources. The mountain national parks -Banff, Jasper, Yoho, Kootenay, Waterton Lakes, Revelstoke and Glacier - in particular, provide a challenge to reclamationists. Harsh climates, poor soil conditions, and large numbers of visitors complicate revegetation efforts.

Parks Canada's objectives for rehabilitation largely match those of other agencies. Erosion control and aesthetic considerations are prime obligations. In addition, reclamation is directed toward re-establishing the dynamic

Canada's national park system has an established program objective.

"to protect for all time representative natural areas of Canadian significance in a system of national parks, and to encourage public understanding, appreciation and enjoyment of this natural heritage so as to leave it unimpaired for future generations" (Parks Canada, 1979). Within this mandate, a dichotomy arises - to preserve ecological integrity while providing opportunities which encourage understanding and enjoyment of the resources.

Visitor opportunities are provided through facilities such as hiking, trails, ski areas, visitor centers and secondary roads. In addition many of the western region parks are dissected by transportation corridors, projects associated with major terrain disturbance. These include the Trans Canada Highway (TCH) twinning in Banff, Canadian Pacific Railway (CPR) mainline improvements in Banff and Glacier, and Canadian National Railway (CNR) line twinning in Jasper.

Rehabilitation is an integral component of minimizing the conflict which arises between these activities and the need to protect natural resources. The mountain national parks -Banff, Jasper, Yoho, Kootenay, Waterton Lakes, Revelstoke and Glacier - in particular, provide a challenge to reclamationists. Harsh climates, poor soil conditions, and large numbers of visitors complicate revegetation efforts.

Parks Canada's objectives for rehabilitation largely match those of other agencies. Erosion control and aesthetic considerations are prime obligations. In addition, reclamation is directed toward re-establishing the dynamic

natural conditions which prevailed prior to disturbance, or toward establishing communities which allow a maximization of use while minimizing impacts.

Reclamation objectives should be established, prior to site planning. New construction projects must adhere to reclamation guidelines established at project initiation. Pre-planning for reclamation on new projects must be incorporated into the development process early. Ideally, rehabilitation concerns should be outlined in the design phase of the project and plans for rehabilitation incorporated into the initial construction. Items such as initial terrain recontouring, topsoil salvage and vegetation salvage must be considered at this stage to be cost-effective.

Soil Stabilization

Glacial till soils are common in the mountain national parks. While these soils are stable when dry, erosion and mudslides occur wherever subsurface seepage has been exposed or has developed as a result of construction activities. Consequently, a variety of slope stabilizing techniques have been tested in the mountain parks.

One of the most effective means of reducing soil instability caused by seepage is the use of mechanical barriers (bin walls or gabions) to reduce slope angle. Bioengineering methods have also been tested. An operational trial using willow cuttings to aid stabilization of a large seepage slope on the Canadian Pacific Railway (CPR) right-of-way at Lake Louise is currently being undertaken. A total of 15000 cuttings (at a density of 50,000 - 100,000 stems/ha) were planted in 1983. This is part of a phased program of slope revegetation and stabilization which also includes a grass-legume cover and ultimately, a tree cover.

Surface erosion has been more successfully managed. The most common techniques involve the use of erosion control fabric. The value of jute netting has long been established but new products also provide surface erosion protection. Paper and nylon netting products (Hold/Gro, Rollite) and excelsior blankets have provided good wind and water erosion control for a variety of disturbed areas. It is vital, however, that the fabric be installed in a manner which ensures close contact with the soil. While staples anchor the material, operational experience has shown improved results where rocks were also used to anchor the fabric. Rocks also improve microclimatic conditions encouraging plant establishment. Erosion control fabric has been used for montane, subalpine and alpine sites in the mountain national parks. Caution must be exercised, particularly in alpine situations, to monitor product deterioration as the biodegradable nature of these products is diminished at high elevations. If left in place for long periods of time, its insulating ability combined with cool spring soils could shorten the growing season and actually reduce the vegetative cover established.

Reinforced nylon netting (Enkamat) has produced mixed success at a very difficult trial location in Jasper National Park. The material was utilized to reduce erosion in an area (approximately 1500 m^2) where a sand lens was eroding on a till cut slope along the Canadian National Railway (CNR) right-of-way. The netting did encourage grass establishment on the area, however it was not adequately anchored and will have to be removed. A soil stabilizer (Urasol) was also applied at this site. While establishment success was improved, the effectiveness of the soil cement was compromised by the presence of bighorn sheep on the slope. Their hooves punctured the surface and reduced effectiveness of the soil

stabilizer. It should be noted however that the hoofprints did provide good microsites for plant establishment.

The final benefit of erosion control fabric is that it serves as a constant reminder to people in recreational use areas that rehabilitation is on-going at a site. It should therefore reduce unnecessary disturbance of newly seeded areas. The importance of appropriate signing to reinforce the rehabilitation concept to the visitor is critical. At an alpine site at Whistlers Mountain in Jasper, the matting was placed in the fall, while the signing was not installed until the following summer. As a consequence, visitors arriving in the early spring when snow was still abundant used the matting as a drier walkway through the meadows.

Soil Amendment

Once erosion has been controlled, seedbed preparation can begin. The importance of topsoil salvage to site potential can not be overemphasized. Past disturbances where mineral soil has been left exposed have proven difficult to revegetate. Soil pH under such conditions approach 9.0. The addition of topsoil from outside the park is discouraged, particularly in isolated and/or alpine locations, due to problems associated with the invasion of exotic species into native communities.

Fertilization improves ground cover. Tests which compare fertilized and unfertilized sites (Windy Point, Jasper and Flints Park, Banff) and different rates of fertilization (Bow Valley Parkway, Banff) have been conducted. Testing for

native and agronomic species reaction to fertilization has improved cover in all the tests conducted. Reaction to fertilization was species specific and diminished as the time from fertilization increased. Most species developed significantly lower percent cover in the absence of fertilization. However, some species (particularly native grass species) achieved good cover either with or without fertilization. For example, at the Flints Park trial in Banff, Festuca saximontana achieved a cover of 32 percent and 25 percent in fertilized and unfertilized plots respectively after two growing seasons. The Bow Valley Parkway test compared fertilizer rates. At that site, the best cover was achieved on the plots which received the heaviest (126 kg N/ha and 96 kg P/ha) fertilization. In this test, the high rate corrsponded with the fertilizer requirement identified through soil testing. The fertilizer application should always be determined through soil nutrient analysis. Operationally, fertilization should occur in the same season as seeding and should continue for three to five years following the initial establishment year. The rate of application should be adjusted annually to match project objectives and plant needs. If a self-sustaining cover is desirable, fertilization should decrease once a productive cover has been attained.

Species Selection

Species selection must be determined by the rehabilitation objectives of the program. The plant material size and seed mixes will vary depending on the time frame established (short and long term) and on the projected use of the area (e.g. wildlife habitat versus recreation). Ideally, species selection will also be based on test results conducted with appropriate species under similar environmental conditions. (Early emergence and long term cover must both be considered.)

Parks Canada's policy dictates that non native species not be introduced (Section 3.2.8, Parks Canada Policy, 1979). Commercial availability of native plant material has restricted the achievement of this objective. To ameliorate the situation, Parks Canada in conjunction with RRTAC had sponsored a native grass breeding program. Through this program native seed was provided for testing under various environmental conditions.

Research plots to assess both native and agronomic grass species have been established in the mountain parks. Test sites include the Bow Valley Parkway, Flints Park, Sunshine Village ski area, Lake Louise ski area, TCH and CPR mainline in Banff National Park; Windy Point, Marmot Basin ski area and Whistlers Mountain in Jasper, and CPR mainline in Glacier National Park. Some of these sites are operational trials (i.e. large scale plots established using techniques which would ultimately be used as apposed to small scale, usually hand-laid plots) as well as research trials. In general, data on early establishment, percent cover over a number of growing seasons reproductive potential, competitiveness and native invasion are collected. The test sites include montane to alpine ecoregions.

The base for many rehabilitation projects is seeding, particularly with grass mixes. The use of legumes in such mixtures has been discouraged in the mountain national parks where conflicts between users and wildlife are anticipated. Elk, deer and bears are all attracted by legumes. It has been recognized, however, that where soil nutrients are limiting, legumes provide necessary nitrogen as well as organic material through plant senescence.

Trials using shrub cuttings, rooted material and transplanted material have all been conducted with good success in montane to alpine environments. Shrub cuttings are among the most economical methods of obtaining large quantities of plant material. A major operational test of willow shrub cuttings has been established along the CPR line at Lake Louise. Although anticipated survival was approximately 50 percent, at the end of the first growing season a survival of 75 percent was achieved. Cuttings collected in the fall had a slightly better survival rate than the spring collected cuttings (86% versus 69%). Shrub survival is often dependent on the moisture conditions prevailing during the establishment year. Sufficient soil moisture must exist to promote root growth. The success of shrub cuttings in stabilizing steep slopes where subsurface water is a problem is enhanced by coinciding initial shrub establishment with low subsurface flow years. This is necessary to ensure that erosion does not jeopardize initial establishment. At such sites, a well-develoed root ball is required to draw moisture away from the seepage area.

Where adequate soil moisture during establishment cannot be guaranteed, rooted cuttings may be preferred. At an alpine site (2260 m asl) on Whistlers Mountain in Jasper, 350 rooted cuttings were planted. The species used included Salix arctica, S. nivalis, Silene acaulis and Sedum sp. The known survival rate averaged 73 percent after two summers and one winter. (The actual survival rate could not be determined as planted specimens could not be readily distinguished from exising plants.)

Sod transplanting has been extensively utilized particularly in alpine situations. Critical factors in plant survival include timing of removal, speed of replacement, and moisture regime at the time of transplanting. It is also important to ensure the entire sod is adequately sealed to the surrounding vegetation. Sods have been successfully transplanted at the following alpine locations; Sunshine Village and Bow Summit in Banff and Revelstoke Summit in Revelstoke-Glacier.

In areas where no formal testing has been conducted, careful recording of techniques and species success will allow operational rehabilitiation to be monitored. Included in this monitoring are the following projects: Whistlers Mountain trail redevelopment, CNR mainline twinning and Marmot Basin ski area in Jasper; TCH twinning, CPR twinning (Lake Louise) Parker's Ridge trail redevelopment and Sunshine ski area in Banff; and CPR twinning in Revelstoke-Glacier.

Parks Canada's rehabilitation program has addressed many interesting situations. Many projects provide a challenge due to their uniqueness.

1. The TCH twinning project in Banff in particular has created a diversity of subjects.

    a) Relocation of an important fish-bearing creek (Chinaman's Creek) necessitated development of a new streambed. Design included not only excavation of the channel and associated bank rehabilitation, but creation of various in-stream habitats to maximize fish utilization. Spawning beds, fry rearing areas and mature fish habitat were produced through both unique engineering design and extensive planting of the stream bottom and banks.

Monitoring of benthic flora and fauna as well as the fish population on-going since the construction was completed has demonstrated almost complete recovery of the stream community.

b) The fencing of the highway to reduce animal mortality resulting from collision with vehicles resulted in a need for animal crossing structures. These underpasses must be landscaped to meet the security requirements of the species which use them.

c) The original highway construction resulted in a series of poorly vegetated, dry, south-facing slopes. A major concern for present rehabilitation involves revegetation of these old slopes and additional similar slopes created by new construction. A research site has been established at Carrot Creek to evaluate various methods of rehabilitation on these slopes. Tests include topsoil addition, jute netting, drip irrigation and mulch addition.

2 Potential loss of animal habitat in the Bow Valley has prompted research into the creation of new elk habitat. In the summer of 1984, work will begin to convert an old landfill site in Banff to winter elk habitat.

3. Alpine rehabilitation is another very important aspect of Parks Canada's revegetation program. Research is on-going to monitor impacts and rehabilitation in order to develop techniques for these severe sites.

Summary

Parks Canada has an obligation through its mandate to minimize the impacts of human use. One of the most important ways of accomplishing this is through rehabilitation. Effective reclamation requires judicious planning, careful site evaluation and monitoring of short and long term results.

It is apparent from the work currently underway in the mountain national parks that reclamation planning must be incorporated into the initial development design if cost efectiveness and options are to be maximized. Rehabilitation objectives and specific site requirements must be identified and incorporated into the design stage of all projects.

Evaluation of each site's capability to sustain plant growth is also critical. Two alternatives - ameliorating site characteristics and selecting plant material capable of survival under existing conditions - can then be assessed. Parks Canada has and will continue to conduct research into species suitability under advserse conditions and various techniques to ameliorate harsh environmental conditions.

Parks Canada's commitment to reclamation will continue through research, and long and short-term monitoring of impacted sites and their rehabilitation.

REHABILITATION OF OIL AND SALT WATER SPILL SITES

Notes Prepared By:
Dan Blackmore P.Ag.

for the

RRTAC Workshop
April 30 and May 1, 1984

TABLE OF CONTENTS

Page

1. OIL 1

1.1 Environmental Effects 1
1.1.1 Movement in Soil 1
1.1.2 Soil Changes 2
1.1.3 Microbial Activities 2
1.1.4 Long-term Soil Changes 3
1.1.5 Plant Growth 4

1.2 Rehabilitation Procedures 5
1.2.1 After-cleanup Assessment 5
1.2.2 Drainage 5
1.2.3 Soil Amendments 6
Fertilizers 6
Lime 7
1.2.4 Soil Mixing and Aeration 7
1.2.5 Soil Sampling 7

2. SALT WATER 11

2.1 Effects on Soil and Vegetation 11
2.1.1 Soil 11
2.1.2 Vegetation 12

2.2 Mitigation and Rehabilitation Procedures 13
2.2.1 Undisturbed Forest and Organic Soil 13
Seepage Water Sampling 13
Soil Sampling 14
Flushing 15
Gypsum 16

Page

Revegetation 17
Fertilization 17
Final Restoration 17
2.2.2 Exposed Mineral Soil 17

1. OIL

1.1 Environmental Effects

1.1.1 Movement in Soil

- The most important factors in the downward movement of oil in soils is soil texture (percent sand, silt and clay), soil moisture content and the amount of oil spilled.

- Oil would tend to move more quickly through sandy soils compared to clay or peat soils.

- Sandy soils hold less oil than clay or peat soils.

- Oil flows more easily into a dry soil than a wet soil.

- Oil will tend to flow overland to the low spots and puddle if the soil is wet.

- If enough oil is present, downward movement will continue until the water table is reached. Oil can then spread out for some distance from the original spill source.

- Heavy oil fractions will tend to accumulate near the soil surface while lighter gasoline-like fractions move further down.

- The volatile oil fractions will tend to dissipate into the atmosphere, particularly on a dry, hot, windy day.

1.1.2 Soil Changes

- Oil soaking into the soil displaces the soil water and the soil air.

- Moisture will evaporate from the soil surface together with lighter volatile fractions. This produces a dry soil.

- Soil aggregates become coated with a thin layer of the heavier fractions, which seals the soil aggregate, preventing entry of oxygen and water. Anaerobic conditions result.

- Water will not freely infiltrate the soil and puddles form on the surface, further aiding anaerobic conditions.

- The light fractions may dissolve the soil humus gums and waxes, resulting in a breakdown of soil aggregates, which tends to further inhibit infiltration of oxygen and water.

- The carbon dioxide produced by micro-organisms cannot be exchanged at the soil surface with oxygen due to poor soil structure and crusting (often as a result of burning) and/or waterlogged conditions.

1.1.3 Microbial Activities

- Initially, microbial activities tend to decrease slightly.

- Then certain species of bacteria are greatly stimulated because hydrocarbons are excellent energy and carbon sources.

- In the microbial process of obtaining energy and carbon from oil, mineral nutrients are tied up in microbial tissue.

- Microbes have first call on nutrients as they occupy sites immediately around the plants root hairs and therefore obtain the nutrients first.

- Increases in bacteria numbers of up to 50 times the previous number have been noted.

- Increases in bacteria number is greatest in aerobic soil because of the good supply of oxygen.

- Some organisms such as fungi and algae tend to decrease in oil-soaked soil and some microbes remain unaffected.

- Microbial activities increase in soil with an oil content of up to 5.5 percent (by weight); however, when the oil content reaches 8.5 percent or greater, the microbial activities decrease because of anaerobic conditions.

1.1.4 Long-term Soil Changes

- Soil organic matter increases as the hydrocarbons are changed to soil humus by the microbes.

- Soil aeration, water holding ability and structural characteristics all improve as oil is decomposed.

- Nitrogen, phorphorus and sulphur are released by mineralization of the previously stabilized oil decomposition products.

- Nitrogen content may increase as the activities of nitrogen-fixing organisms increase.

- No generalizations can be made about how the soil pH is affected by oil. Some studies indicate the soil is somewhat acidified and some studies indicate the soil is buffered. Soil testing is required in each individual case.

1.1.5 Plant Growth

- Oil has a direct herbicidal effect on plants when it is in contact with foliage and root systems.

- Plants less sensitive to the herbicidal effects of oil would have thick, waxy leaves (e.g. bearberry), root systems or plant parts that can regenerate (e.g. willow) and leaf shapes that reduce interception of oil (e.g. grass and sedges).

- Oil penetrates plants mainly through the stomata. Lighter fractions can enter by diffusing directly through the leaf surface.

- Photosynthesis is stopped by the oil dissolving certain cell parts and by filtering out sunlight.

- Plant death will also result from oil spills through the oil's effect on nutrient deficiency, oxygen deficiency, toxic decomposition products and/or drought. Plant growth can usually be easily established once these detrimental conditions are corrected.

- An oil content of two to four percent can seriously affect germination in mineral soil. Germination in organic soil is much better with a similar oil content.

- It has been noted that weed species such as dandelion, Canada thistle and perennial sow thistle appear to tolerate oil-soaked soil very well and are often the first plants to establish.

- Old, barren areas that seem not to support vegetation are possibly in this situation because there may be no seed or rhizomes present to re-establish vegetation.

1.2 Rehabilitation Procedures

No two spills are exactly the same; therefore, each rehabilitation program will be site-specific. The following guidelines are intended to assist in developing a rehabilitation program:

1.2.1 After-cleanup Assessment

- Determine the:
  a) kind of oil spilled (e.g. is salt involved?);
  b) quantity spilled;
  c) areas affected with different spill intensities (flagging may be an excellent idea);
  d) nature of the soil (usually a soils expert is required); and
  e) soil sampling regime to be set up in both the contaminated area and in an adjacent uncontaminated area. The sample from the uncontaminated area will be your control for comparison with the contaminated area.

1.2.2 Drainage

- Drainage is a useful operation only if it is accompanied by a soil mixing operation.

- The value of drainage is:
  a) to allow oxygen into the soil and carbon dioxide out of the soil; and
  b) to facilitate mechanical operations.

- After drainage, if the soil is not tilled, a surface crust may form and anaerobic conditions may result.

- Most grasses and legumes used in revegetation require some drainage.

1.2.3 Soil Amendments

Fertilizers

- Recommendation for fertilizers will be based on the results of soil analyses. Of particular note will be the percent of oil found in the soil and the nitrogen, phosphorus, potassium and sulphur content of the soil.

- As an example, the first application might contain:
  223 kg/ha (200 lbs/ac) of N,
  111 kg/ha (100 lbs/ac) of P_2O_5,
  111 kg/ha (100 lbs/ac) of K_2O,
  28 kg/ha (25 lbs/ac) of S.

- As a general rule, apply addition nitrogen wherever the nitrate-nitrogen levels in the surface 15 cm (6 inches) fall below 55 kg/ha (50 lbs/ac) or 10 to 30 ppm in the growing season.

- The nutrient additions at every site will be different, there fore, soil sampling and analysis are very important.

- When nitrogen starts to recycle, as indicated by soil analysis, more normal levels (lower) of nitrogen may be applied.

- Phosphorus and potassium should be added only if the soil test indicate a deficiency.

- Peat soils will generally need added potassium; whereas, most heavy textured mineral soils (clay) will not.

- High rates of nitrogen as Ammonium Sulphate (21-0-0) is not recommended as it may contribute to the acidity of the soil.

Lime

- Lime should only be added if the soil test indicates a low pH.

1.2.4 Soil Mixing and Aeration

- Mixing of the top 15 cm (6 inches) of the soil is necessary in many cases to increase aeration of the soil, which promotes microbial activities and results in an increased rate of oil decomposition.

- Never bury oil.

- Fertilizers should be mixed into the soil for maximum effectiveness.

- A rotovator or double disc is the best machine; however, any way of breaking the surface crust will be helpful.

- Intensive or multiple tillage is not necessary; however, soil mixing should take place after each fertilizer application.

1.2.5 Soil Sampling

- Establish a pre-scheduled program of soil sampling which is specific to each site.

- As a general rule, sampling could take place:
  a) immediately after the spill;
  b) three weeks after the first fertilizer application if conditions are moist and warm which encourages rapid microbial activities; and
  c) every three to six weeks during the growing season until the test results indicate the nutrient levels are stabilizing.

- Generally, revegetation programs can be initiated when the soil oil content is less than four percent.

- After a vegetative cover has been established, it will be necessary to sample the soil again to ensure adequate nutrient levels before declaring the site restored.

- Soil samples should be analyzed for pH, conductivity, sulphate, nitrogen, phosphorus, potassium, moisture, oil content, organic matter and ask for a fertilizer recommendation.

TABLE 1

Yields of Barley (Bus./Acre) on Mineral Soil At Ellerslie Following Crude Oil Application in 1973

Trts.	1974	1975	1976
Control			
Fert.	85	65	90
No Fert.	70	78	85
6% Crude			
Fert.	Nil	40	80
No Fert.	Nil	5	30
11% Crude			
Fert.	Nil	Nil	55
No Fert.	Nil	Nil	2

This table was summarized from Toogood (1977) to show the general effects of fertilization on soil rehabilitation and subsequent crop production after an oil spill. For fuller details of the experiment, refer to:

Toogood, J.A. 1977. The reclamation of agricultural soils after oil spills. Part 1: Research. Alberta Institute of Pedology. Pub. No. M-77-11. University of Alberta. Edmonton, Alberta.

TABLE 2

Effects of Various Treatments on Yield
Of Plant Material (kg/ha dry wt.) at a Bog
Oil Spill Site in the Swan Hills

Trts.	1973	1975
Undrained		
Nil	Nil	Nil
NPKS	Nil	15
NPKS & Mixing	Nil	76
NPKS & Mixing & Lime	Nil	236
Drained		
Nil	Nil	Nil
NPKS	7	15
NPKS & Mixing	310	244(1974)
NPKS & Mixing & Lime	685	2197

This table was summarized from McGill and Nyborg (1975) to show the general effects of various treatments. For fuller details of the experiment, refer to:

McGill, W.B. and Nyborg, M. 1975. Reclamation of wet forest soils subjected to oils spills. Alberta Institute of Pedology. Pub. No. G-75-1. University of Alberta. Edmonton, Alberta.

2. SALT WATER

2.1 Effects on Soil and Vegetation

The dominant salt in oil field brine is sodium chloride (NaCl), which may be twice as salty as sea water. Produced salt water analysis has shown chloride content from 15 000 to 150 000 ppm. The three basic ecological problems with salt are: they are non-biodegradable, chloride is highly toxic and sodium is a long-term soil contaminant.

2.1.1 Soil

- Following a salt water spill, sodium and chloride come into contact with the soil surface and attach themselves to the soil granules and particles.

- At the first heavy rainfall, sodium and chloride are leached into the soil profile.

- As sodium saturates the cation exchange complex, the soil becomes subject to dispersion. This process causes the soil particles to disintegrate and the soil air spaces become clogged with dispersed clay and organic matter.

- The soil then forms a hard impervious layer with a high concentration of salt underneath.

- Water cannot pass through and surface ponding occurs.

- The dispersion hazard is much lower in undisturbed forest soils with an organic mat and a permanent undisturbed soil structure.

- Dispersion and subsequent ponding do not occur as readily in coarse textured sandy soils.

- The chloride ion is very mobile in the soil solution and leaches both downward and laterally more readily than sodium.

- Sodium is leached from the cation exchange complex after the addition of calcium; however, sodium can re-salinize the topsoil by upward moisture movement. Moisture evaporates from the soil surface and is replaced by moisture migrating upwards, which carries the salt back to the surface.

2.1.2 Vegetation

- Plant will start to die very soon after the salt water spill has occurred.

- All forest vegetation is subject to killing from initial salt shock.

- Plant death results from high osmotic and nutrient stress and the uptake of toxic chemicals such as chloride.

- Plant can accumulate both sodium and chloride from the soil and the visual symptoms include foliar discoloration and injury, cambium injury, root injury and the subsequent death of the plant.

- Rates of uptake and injury or death depend on species. For example, black spruce takes up sodium and chloride more slowly than many species, while birch displays more tolerance than many species.

- Most of the direct herbicidal injury to plants is caused by chloride, as it is considered highly toxic.

2.2 Mitigation and Rehabilitation Procedures

Mitigation and rehabilitation techniques for organic forest soil and disturbed exposed mineral soil (e.g. agricultural) are different. The following are general procedures on which a specific rehabilitation plan for each individual spill site can be developed.

2.2.1 Undisturbed Forest and Organic Soil

- Contain and recover any recoverable salt water with trenches and/or bell holes as required.

Seepage Water Sampling

- To initially determine the extent of the surface contamination, 30 cm (12 inch)-deep holes can be dug with a hand auger or natural water filled depressions can be sampled at various locations down the slope from the spill site. Be sure to sample in uncontaminated adjacent areas to determine the normal salt content of the soil.

- In clay soil, the holes should be filled with water.

- A conductivity reading of 500 ppm or greater will usually indicate salt contamination.

- On flat or depressional areas auger the holes to 90 cm (35 inches) and check for salt.

- If no seepage is present, make a slurry from the soil and check for salt in the same way as with seepage water.

- In this way, the boundaries of the spill area can be determined and flagged.

Soil Sampling

- Soil sampling should be started at the time containment and recovery are underway.

- From the initial spill site diagram, set up a regime of soil sampling to determine depth and severity of contamination.

- Take samples from both the contaminated area and adjacent uncontaminated areas (both sides of the spill area). The control samples (uncontaminated area) should be taken from the same slope position as their counterparts in the spill area.

- Mark each soil sampling spot so that later samples can be taken at the same place, e.g. labelled stakes.

- Sample as follows:

Surface to mineral soil (organic matter)
0-8 cm
8-15 cm
15-30 cm
30-60 cm
60-90 cm
90-122 cm

- The sample should be analyzed for:

pH
soil texture
electrical conductivity
sodium
potassium
calcium
magnesium

chloride
sulphate
carbonate
bicarbonate

Soil Analysis Interpretation

below 4.2	Too acid for most plants.
4.2-5.5	Suitable for acid tolerant plants.
5.5-8.4	Suitable for most plants.
above 8.4	Too alkaline for most plants, indicates problems from high sodium in soil.

Electrical Conductivity (mmhos/cm)

less than 2	No salinity problems.
2-4	Restricts growth of salt sensitive plants.
4-8	Restricts growth of most plants.
8-16	Restricts growth of all but salt tolerant plants, reduces or prevents germination of most plants.
more than 16	Prevents germination and growth of all but very tolerant plants.

Flushing

- As early as possible, use fresh water or, more ideally, water saturated with gypsum to flush the site.

- Adjust the flush rate to allow penetration into the soil, but not result in overland flow. The aim is to get seepage through the soil rather than on the surface.

- Flushing should continue until the chloride level reaches 500 to 1000 ppm.

- Allow the area to drain for three or four days.

- Apply a second flushing until the seepage water has a chloride level of 500 ppm.

- Check the seepage water every three or four days and, if the chloride level remains below 500 ppm, additional flushing will not be necessary.

- Flush a third time if the reading rises above 500 ppm.

- Flushing is intended to: 1) dilute the salt; 2) increase the runoff; and 3) minimize the salt infiltration rate.

Gypsum

- As soon as possible, apply gypsum (calcium sulphate - $CaSO_4$) at 6.7 tonnes/hectare (3 tons/acre).

- Apply by hand, directly to the forest floor. Avoid spreading the gypsum on foliage if possible. Cyclone spreaders are not recommended because of drift.

- The first application should take place immediately after flushing has been completed.

- Avoid any surface disturbance. If small bare patches of mineral soil exist, cover them with peat moss.

- Repeat gypsum applications in the spring for two more years will probably be required. Soil samples analysis will determine when more gypsum is needed.

- The gypsum treatment is necessary so that the calcium ion will displace the sodium ion from the soil colloids and sodium will be leached out of the profile.

Revegetation

- One week after the final flush, seed the site with a salt tolerant mixture at a rate of 56 kg/ha (50 lbs/ac) in forested areas. Half that rate can be used on agricultural land.

Fertilization

- After seeding, fertilize with nitrogen, phosphorus and potas sium fertilizer.

- Nitrogen Sources: 1) First choice is calcium nitrate ($CA(NO_3)_2$) (15.5-0-0); 2) Second choice is ammonium nitrate (34-0-0); 3) Third choice is urea (46-0-0).

- Apply nitrogen at 67 kg/ha (60 lbs/ac) on an elemental basis.

- Phosphorus Source: Ammonium phosphate (11-55-0) at 22 kg/ha (20 lbs/ac) on an elemental basis.

- Potassium Source: Potassium chloride (0-0-60) at 22 kg/ha (20 lbs/ac) on an elemental basis.

Final Rehabilitation

- When a good vegetative cover has been established, the trenches and/or bell holes can be backfilled and seeded.

2.2.2 Exposed Mineral Soil

- Contain and recover any recoverable salt water.

- DO NOT FLUSH.

- Set up a soil sampling regime as outlined in Section 2.2.1.

- Spread gypsum, at 22 tonnes/ha (10 tons/acre or 460 lb/1000 sq. ft.) and incorporate into the top 15 cm (6 inches) of soil.

- Spread 5 cm (2 inches) of manure or peat moss on the soil surface and incorporate into the top 15 cm (6 inches).

- Seed a salt tolerant seed mixture at 28 kg/ha (25 lbs/ac).

TABLE 3

Effects of Gypsum and Deep Plowing
On Exchangeable Sodium Percent - Idaho

Trts.	1959	1960	1961	1962
Check	30	26	20	25
Gypsum	30	12	15	10
Deep Plowing	30	22	18	12
Gypsum & Deep Plowing	30	8	5	4

This table was summarized from graphs presented by White and de Jong (1975); from Rasmussen et al (1972). For fuller details, refer to:

White, R.A. and de Jong, E. 1975. Reclamation of salt and oil damaged soils. A literature review of potential methods for use in oil fields in Saskatchewan. Saskatchewan Institute of Pedology. Pub. No. M27. University of Saskatchewan. Saskatoon, Saskatchewan.

Rasmussen, W.W., Moore, D.P. and Alban, L.A. 1972. Improvement of a Solonetzic (slick spot) soil by deep plowing, subsoiling and amendments. Soil Sci. Soc. Amer. Proc. 36: 137-142.

TABLE 4

Percent of Living Vegetative Cover
On Forested Soils - Swan Hills

Trts.	1978	1979	1981
Control	135	122	163
Brine & Flush	5	30	114
Brine & Flush & Gypsum	20	39	153
Brine	5	15	70

This table was summarized from Hettinger (1983) to show the effects of flushing and gypsum on the survival of forest vegetation following a salt water spill. For fuller details of the experiment, refer to:

Canadian Petroleum Association. Undated. Reclamation of brine spills in upland boreal forest areas. Part 1: Research. CPA 1500, 633-6 Ave. S.W., Calgary, Alberta.

Hettinger, L. 1983. in: Follow-up study. Reclamation of brine spill affected sites in upland boreal forest areas. Canadian Petroleum Association. Pub. No. EC-90040. Calgary, Alberta.

PRE-GERMINATION TREATMENTS FOR SELECTED WOODY PLANT SPECIES NATIVE TO THE EASTERN SLOPES

P. King[1], G. Grainger[2] and A. Straka[2]

1. INTRODUCTION

A major criterion in Alberta for judging the success of reclamation on industrially disturbed areas is the restoration of pre-disturbance productivity. Native trees and shrubs having value for recreation, watershed, timber, wildlife or livestock use as well as for soil stabilization, site amelioration or aesthetic plantings may be effectively used in reclamation.

In order for a woody plant species to be used in reclamation operations, it must first be feasible for it to be propagated. One approach commonly pursued is propagation from seed as this lends itself to mechanized, large-scale, economic and flexible bare root and container stock production. The research programme reported in this paper deals exclusively with seed propagation.

Various aspects of this seed propagation research programme have been reported. Native woody plant species having potential for reclamation use in the Rocky Mountain Eastern Slopes of Alberta have been listed and the information pertaining to their propagation from seed was reviewed (King 1980). Within the candidate listing, those species whose seeds were considered as difficult to germinate or whose literature was deficient were iden-

---

[1] Reforestation and Reclamation Branch, Alberta Forest Service, Alberta Energy and Natural Resources, Edmonton, Alberta.

[2] Alberta Tree Nursery and Horticulture Center, Alberta Agriculture, Oliver, Alberta.

tified as needing research (King 1981). The initial phase of the seed pre-germination treatment testing was reported in King, Grainger and Straka (1983).

Those species on which research has been carried out are listed in Table 1. In the following sections of this report, an updated summary is given of the literature and the cumulative experimental results are presented for the more successful species tests. Information on any species experiments not included is available (King, Grainger and Straka, 1983).

2. AMELANCHIER ALNIFOLIA

2.1 Summary Of Literature
(Updated from King 1980)

Freshly collected seed may not be dormant, although some seed lots may contain a large proportion of immature embryos. Dormant seed will require cold stratification for up to 180-200 days prior to sowing. Warm stratificaiton for up to four months prior to cold stratification may be beneficial, particularly in those seed lots with immature seeds. Responses to pre-germination treatments among seed lots may be highly variable.

Impermeability of the seed coat is not a cause of dormancy in the species.

2.2 Seed Pre-Germination Treatment Testing

To date, one factorial experiment has been carried out on a single seed lot of Amelanchier alnifolia. The design employed in this experiment

Table 1

NATIVE WOODY PLANT SPECIES INVESTIGATED IN SEED PRE-GERMINATION TREATMENT TESTING

Scientific Name	Common Name(s)
Amelanchier alnifolia Nutt.	saskatoon, serviceberry, juneberry, shadbush
Arctostaphylos uva-ursi (L.) Spreng.	bearberry, kinnikinnik
Elaeagnus commutata Bernh.	silverberry, wolf willow
Juniperus communis L.	common juniper
Rosa acicularis Lindl.	prickly rose
Rosa woodsii Lindl.	Fendler woods rose, common wild rose, woods rose
Rubus parviflorus Nutt.	thimbleberry
Rubus strigosus Michx.	wild red raspberry
Shepherdia canadensis (L.) Nutt.	Canadian buffalo berry, russet buffalo berry, soapberry
Sorbus scopulina Greene	Greene's mountain ash, mountain ash

NOTE: Nomenclature follows that of Moss 1959.

is summarized in Table 2. Additional information on the methodology used is presented in Appendix 1.

The germination results obtained in this experiment are given in Figure 1.

The seeds of Amelanchier alnifolia are dormant. Without pre-germination treatment by stratification appreciable levels of germination were not attained. The maximum germination obtained in the experiment was 84 percent in response to 150 days of simple cold stratification.

The effects of cold stratification treatments were significant in the experiment. Higher levels of germination were obtained from longer periods of cold stratification. It should be noted that pre-germination treatment by cold stratification alone for periods of 120 days or less yielded relatively incomplete levels of germination. Cold stratification for periods greater than those used in the experiment may have resulted in even higher germination.

Warm stratification treatment effects were not significant although, when used with cold stratification of less than 150 days, greater germination occurred than with cold stratification alone. However, this may have little practical importance since a greater amount of germination was obtained in response to simple cold stratification for 150 days than in any of the combined warm-and-cold stratification treatments, all of which comprised longer total treatment times.

The leaching of seed for 24 hours in distilled water or a gibberellic acid (GA_3) solution prior to the application of stratification treatments yielded greater germination averaged over warm and cold stratification treatments than resulted from the use of stratification alone. The increase

Table 2

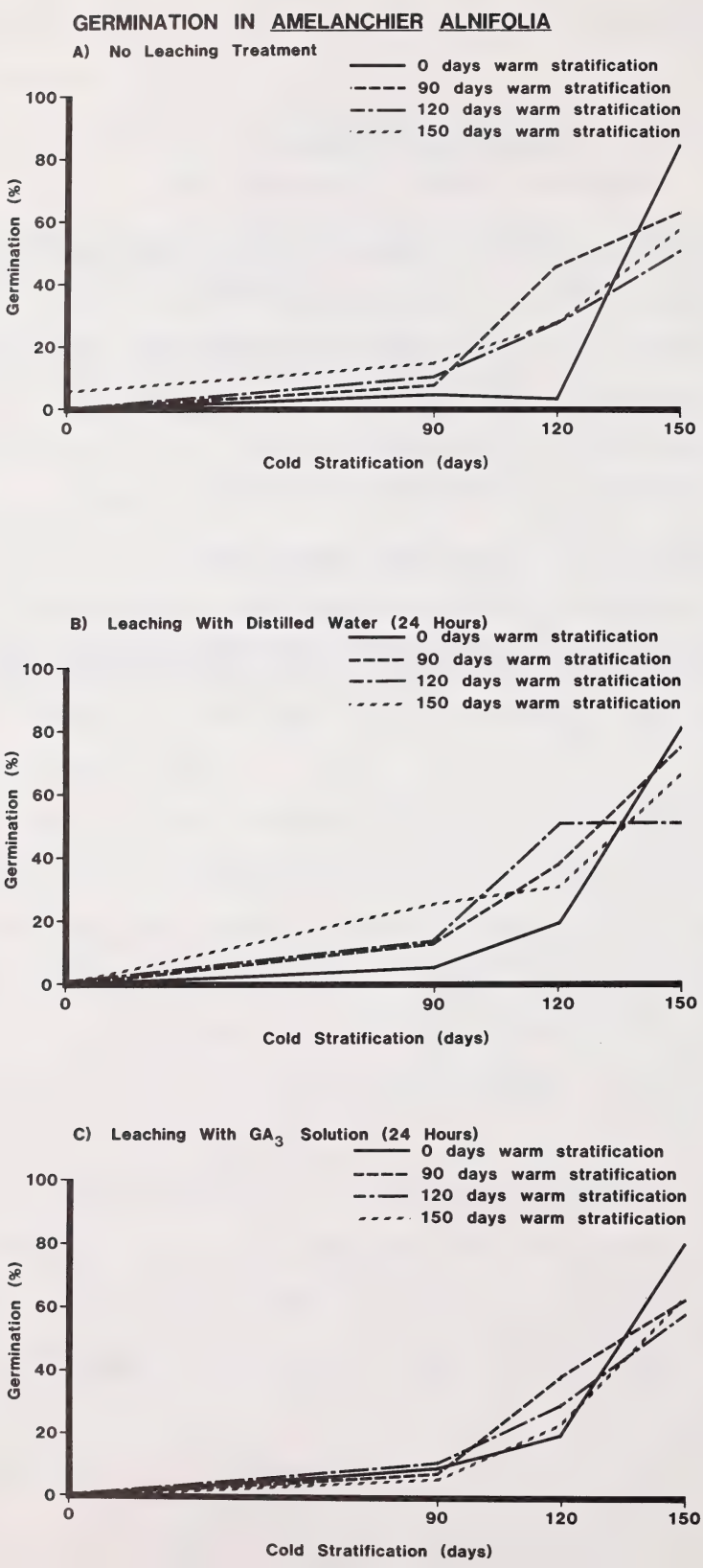
FACTORS AND TREATMENTS IN

AMELANCHIER ALNIFOLIA EXPERIMENT (1984)

Factor	Treatments
Leaching	No leaching, 24 hours leaching in distilled water, and 24 hours leaching in GA_3 solution (250 ppm)
Warm Stratification	0, 90, 120, and 150 days
Cold Stratification	0, 90, 120, and 150 days

NOTE: In the experiment, leaching preceded all other treatments while warm stratification was applied prior to cold stratification.

FIGURE 1


GERMINATION IN AMELANCHIER ALNIFOLIA
A) No Leaching Treatment
0 days warm stratification
90 days warm stratification
120 days warm stratification
150 days warm stratification
Germination (%)
Cold Stratification (days)
B) Leaching With Distilled Water (24 Hours)
C) Leaching With GA3 Solution (24 Hours)

in germination resulting from leaching was greater for distilled water than for the GA_3 solution. However, it must be noted that leaching treatments did not affect the level of germination obtained in response to 150 days of cold stratification. Presumably, 150 days of cold treatment meets the "after-ripening" requirements of this species and additional pre-germination treatment by leaching is superfluous.

The practical significance of the leaching results is the possibility of their use as a supplemental treatment with shorter periods of stratification. The theoretical importance is the suggestion of water-soluble germination inhibitors playing a role in the dormancy of A. alnifolia although, these inhibitors do not exclusively control the germination of saskatoon seed: leaching did not induce germination without stratification treatments.

2.3 Conclusions

The seeds of the Amelanchier alnifolia seed lot which was tested were dormant and required stratification to germinate appreciably. Cold stratification for 150 days gave maximum germination of 84 percent. The use of warm stratification itself did not affect germination but when used prior to cold stratification, it did in some instances yield greater levels of germination than simple cold stratification. The use of leaching with distilled water or a gibberellic acid solution in conjunction with stratification treatments may increase germination levels above those obtained from stratification alone.

3. ELAEAGNUS COMMUTATA

3.1 Summary Of Literature
(Updated from King 1980)

The endocarp of Elaeagnus commutata contains a water-soluble germination inhibitor. The seed coat may retard water uptake but is not impermeable. Some seed lots are dormant while others do not appear to be. Cold stratification for up to 90-110 days is required to overcome seed dormancy.

3.2 Seed Pre-Germination Treatment Testing

A factorial experiment has been carried out on Elaeagnus commutata using excision and seed origin factors. The treatments used in this experiment are summarized in Table 3. Additional information on the methodologies is summarized in Appendix 1.

The germination data for this experiment is presented in Figure 2.

Entire seeds germinated incompletely while those from which the endocarp and testa had been removed germinated fully. The embryo of silverberry is non-dormant and dormancy in the species is entirely a function of the properties of the endocarp and/or testa.

In the experiment, the effects of seed origin was not significant. For the seed lots tested, the germination obtained was independent of origin and the causal agent of dormancy did not vary.

Another factorial experiment on a single seed origin has also been carried out. The factors were running water leaching at approximately

Table 3

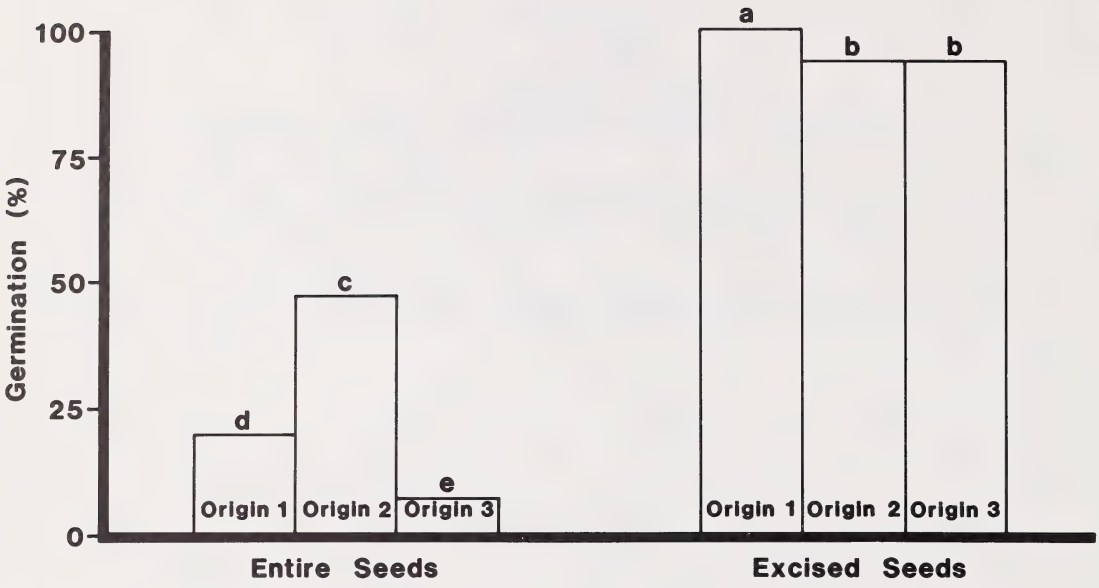
FACTORS AND TREATMENTS IN

ELAEAGNUS COMMUTATA EXPERIMENT (1984)

Factor	Treatments
Excision	Unexcised (Entire Seeds) And Excised Embryos
Origin	Origin #1, Origin #2 And Origin #3 (See Appendix 1)

FIGURE 2

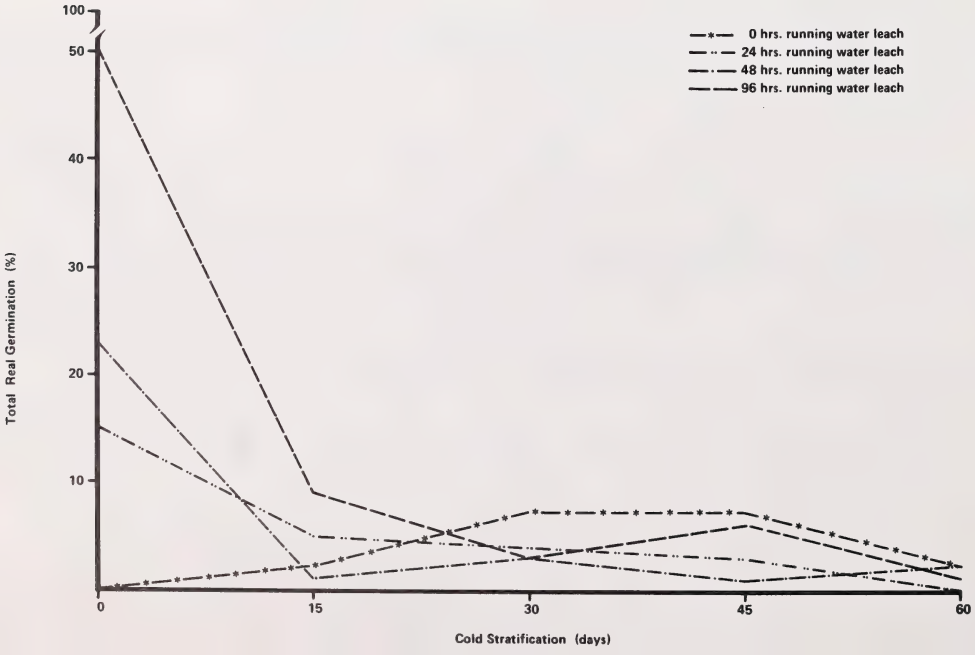
GERMINATION IN UNTREATED ENTIRE AND EXCISED ELAEAGNUS COMMUTATA SEEDS



Germination levels labelled with the same letter are not significantly different at the 1% level, Ducan's Multiple Range Test.

FIGURE 3

TOTAL GERMINATION IN *ELAEAGNUS COMMUTATA* SEEDS



0.5 litres per minute and cold stratification. The treatments used in the experiment are given in Table 4. Complete information on the experimental methodology is presented in King, Grainger and Straka (1983).

Figure 3 presents the germination data from this experiment.

Seeds which were not subjected to any pre-germination treatment failed to germinate, the seeds of the silverberry lot tested were dormant. Cold stratification treatments for up to 60 days resulted in only two to seven percent germination. The combined water leaching-cold stratification treatments gave no or relatively little germination. None of these appear to have potential as pre-germination treatments.

All seed samples treated with water leaching alone had greater levels of germination than any of the cold stratification or compound leaching-cold stratification treatments. In the leaching treatments, the level of germination was proportional to the duration of the leaching, with maximum germination of 50 percent being obtained in response to 96 hours of leaching. The germinative response to water leaching suggests that dormancy is largely the result of water-soluble germination inhibitors. This is confirmed by the literature.

Subsequent to the experiment described above, a number of preliminary tests for further experiments has been carried out. They variously examined longer leaching durations, greater leaching rates and higher leaching temperatures than used previously. None of these appeared to be beneficial to increase maximum germination further.

A recent preliminary experiment included treatments varying germinator conditions. The test results indicate that large increases in germination may be possible from modification of germination test conditions when water leaching is also employed.

Table 4

FACTORS AND TREATMENTS IN

ELAEAGNUS COMMUTATA EXPERIMENT (1983)

Factor	Treatments
Leaching	0, 24, 48, and 96 hours
Cold Stratification	0, 15, 30, 45, and 60 days

NOTE: In the experiment, leaching treatments preceded cold stratification.

3.3 Conclusions

In silverberry the embryos are non-dormant and dormancy is entirely the result of the properties of the seed coverings. This does not vary by seed origin.

Moderate levels of germination have been attained by leaching seeds with running tap water. Increasing leaching rate, leaching duration, and the temperature of the water used in leaching does not appear to be useful in increasing germination further. However, changes in the germination testing regime may result in greater germination.

4. ROSA ACICULARIS

4.1 Summary Of Literature

(Updated from King 1980)

Seeds of Rosa acicularis exhibit deep physiological dormancy. The major causes of seed dormancy in the species appear to be the presence of the testa and the physiological condition of the embryo. The role of the pericarp in dormancy is apparently minor.

Pre-germination treatments may include cold stratification for up to five months, sulphuric acid scarification for one-to-two hours prior to cold stratification for approximately three months, or warm stratification for two-to-four months followed by cold stratification for about three months.

The role of fruit and seed ripeness in dormancy and germination has been studied for some members of the genus Rosa. In these studies it

has been found that germination and the level of inhibitors (in the hips, fruit, and seed embryo) is related to the stage of fruit and seed development.

Water leaching in seeds of one Rosa species has proven to be beneficial to remove inhibitors and increase germination. Evidence of water-soluble inhibitors has been indicated in R. acicularis.

4.2 Seed Pre-Germination Treatment Testing

A factorial experiment has been carried out using hip ripeness at the time of seed collection, warm stratification, and cold stratification as factors. In the first, the treatments were labelled as "not fully ripe" (on the date of seed collection the hips were yellowish-orange in colour and their texture was quite firm) and as "fully ripe" (the hips were collected on the same day and were deep red and firm). Additional information on the experimental treatments is given in Table 5. Detailed information on methodology is available from King, Grainger and Straka (1983).

The results of this experiment are presented in Figure 4.

The seed of Rosa acicularis is dormant, without stratification germination was not appreciable. Maximum germination across ripeness treatments was obtained in response to warm stratification for 60 days followed by 120 days of cold stratification. These were 54 and 36 percent, respectively, in seeds from the "not fully ripe" and "fully ripe" collections.

Ripeness treatments were significant in the experiment. Greater germination was obtained in seed derived from "not fully ripe" hips than in those from "fully ripe" when treated with cold stratification or sequential warm and cold stratification treatments. The practical importance of this

Table 5

FACTORS AND TREATMENTS IN

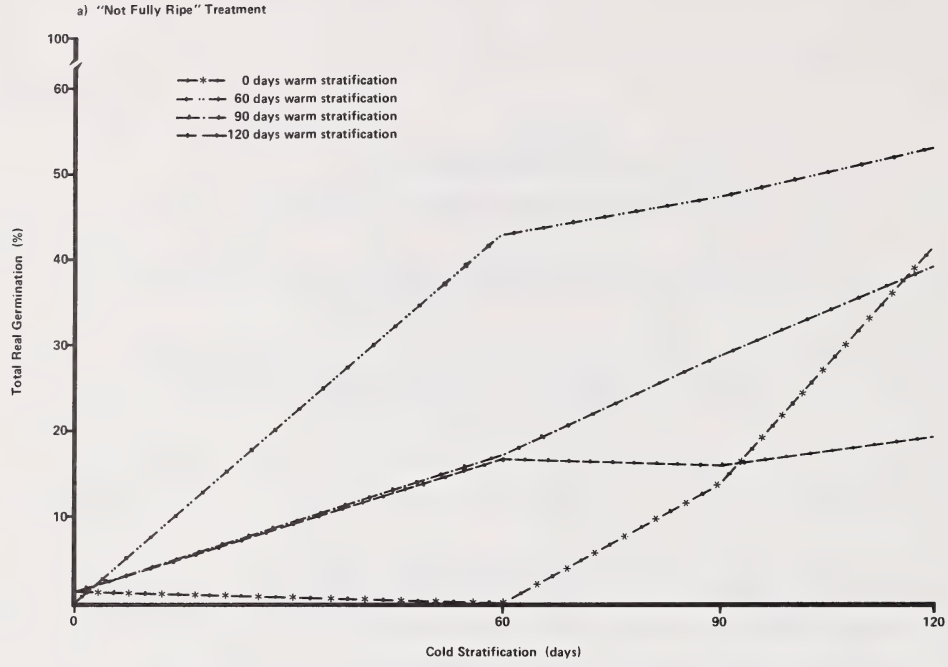
ROSA ACICULARIS EXPERIMENT (1983)

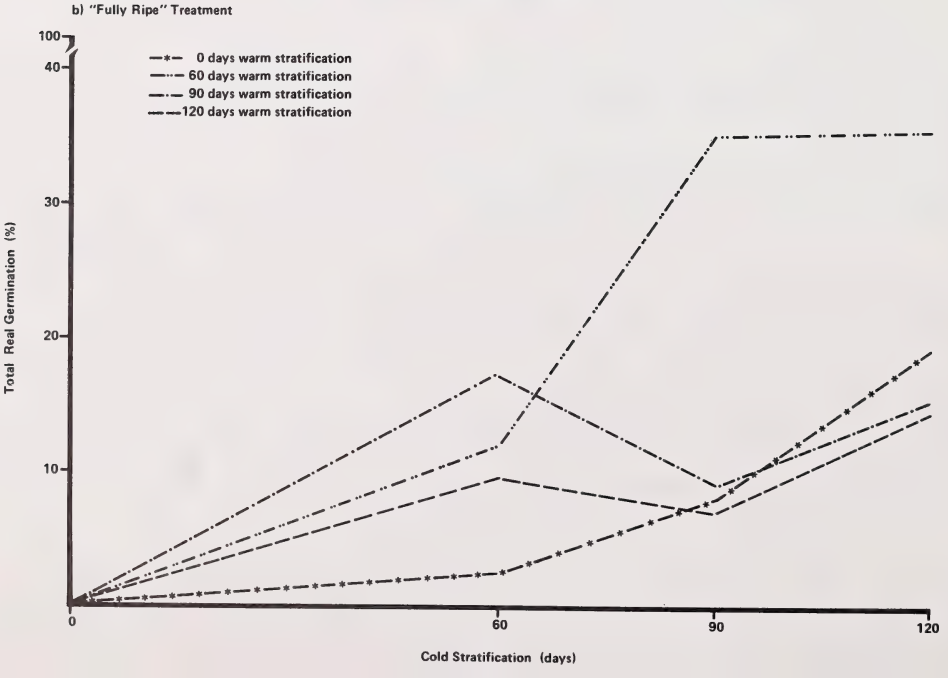
Factor	Treatments
Ripeness	"Not Fully Ripe" and "Fully Ripe" (as described in text)
Warm Stratification	0, 60, 90, and 120 days
Cold Stratification	0, 60, 90, and 120 days

NOTE: Warm stratification treatments preceded cold stratification in the experiment.

FIGURE 4

TOTAL GERMINATION IN *ROSA ACICULARIS* SEED





result is the suggestion that seed collections in Rosa acicularis may be carried out earlier than has been traditional and that such collection will yield greater germination.

Warm stratification effects were also significant. When used in conjunction with cold stratification, germination increased as the duration of warm stratification increased to 60 days while longer periods decreased germination levels relatively. Warm stratification alone gave very little, or no, germination. Combinations of warm and cold stratification generally resulted in greater levels of germination than were obtained with cold stratification alone.

Germination in the experiment was proportional to the duration of cold stratification. Increasing the length of the cold stratification treatment yielded higher germination. Longer periods of cold stratification than the maximum used may have resulted in even greater germination.

It should be noted that an identical experiment to that described above was carried out on seeds of Rosa woodsii. Both the levels of germination obtained and the analysis of the results were very similar to R. acicularis. A full description of the experiment is presented in King, Grainger and Straka (1983).

A second experiment was conducted on R. acicularis to examine the utility of water leaching in increasing germination or decreasing pre-germination treatment times, to refine the periods of warm stratification used for pre-germination treatment and to further test the effects of cold stratification (including a longer period than used previously). Table 6 summarizes the factorial design. Further information on the methodology is given in Appendix 1.

Table 6

FACTORS AND TREATMENTS IN

ROSA ACICULARIS EXPERIMENT (1984)

Factor	Treatments
Water Leaching	0, 24, 72, and 144 hours
Warm Stratification	0, 28, 42, and 56 days
Cold Stratification	28, 56, 84, and 140 days

NOTE: In the experiment, leaching preceded all other treatments while warm stratification was applied prior to cold stratification.

Figure 5 gives the results of this experiment.

Maximum germination of approximately 70 percent occurred in response to 28 or 42 days of warm stratification applied prior to cold stratification for 140 days. As in the previous experiment, warm stratification alone and cold stratification applied for the shorter durations resulted in incomplete germination.

The effects of water leaching treatments were not significant. Leaching treatments neither affected germination when averaged over stratification treatments nor reduced the necessary duration of stratification. Operationally, no benefit would result from the use of water leaching.

The use of warm stratification increased germination. Averaged for leaching and cold stratification treatments, the greatest germination within warm stratification was in response to its use for 56 days. However, in unleached seeds, the use of 56 days of warm stratification suppressed germination relative to that obtained from both 28 and 42 days when 140 days of cold stratification was also used.

Cold stratification effects were significant. Germination was proportional to the length of the cold stratification treatment. The greater the duration of cold stratification, the greater the germination obtained. Yet longer periods of cold stratification may yield greater germination.

4.3 Conclusions

Seeds of Rosa acicularis are deeply dormant. Untreated seeds failed to germinate appreciably while even long periods of cold stratification

FIGURE 5

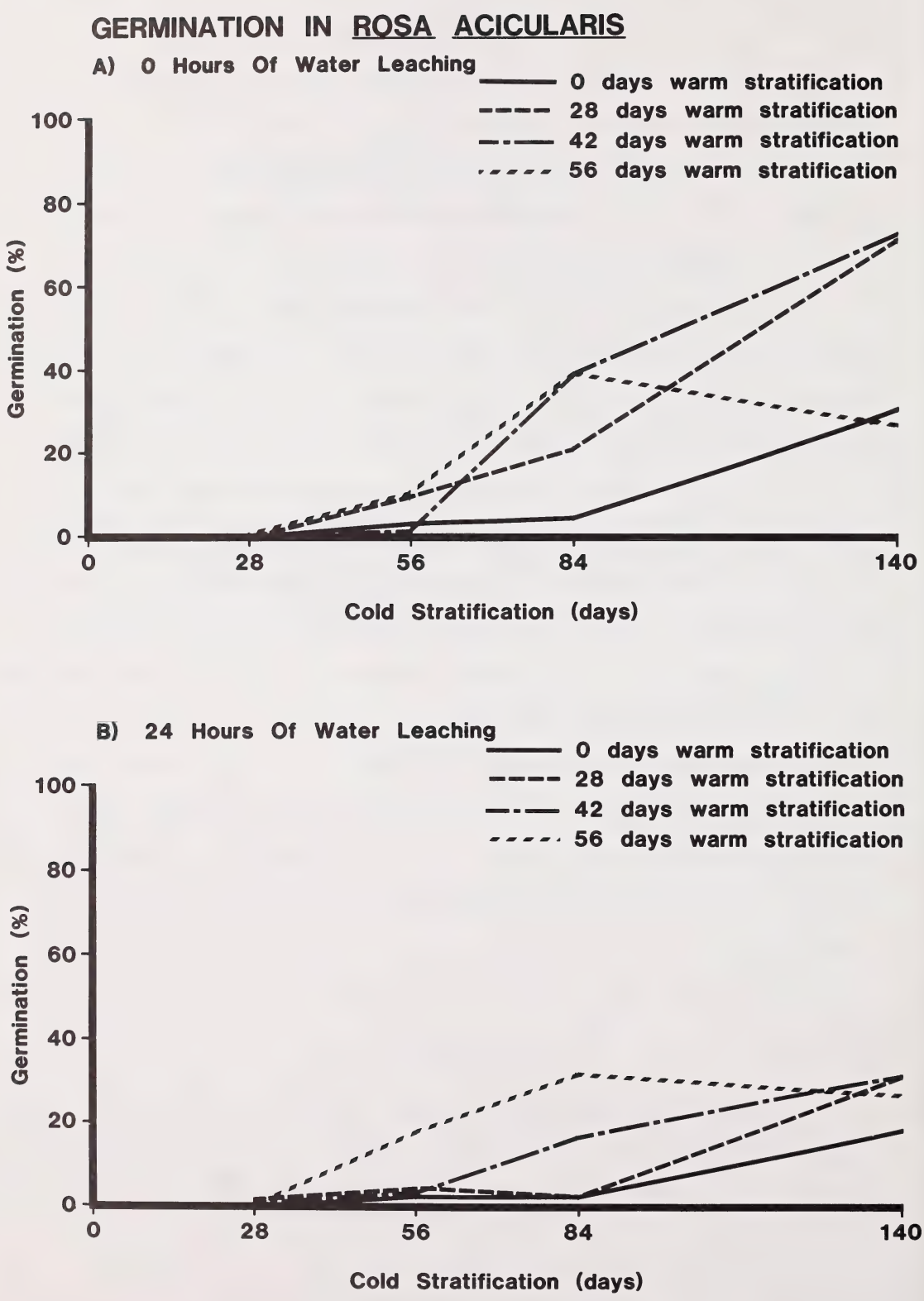
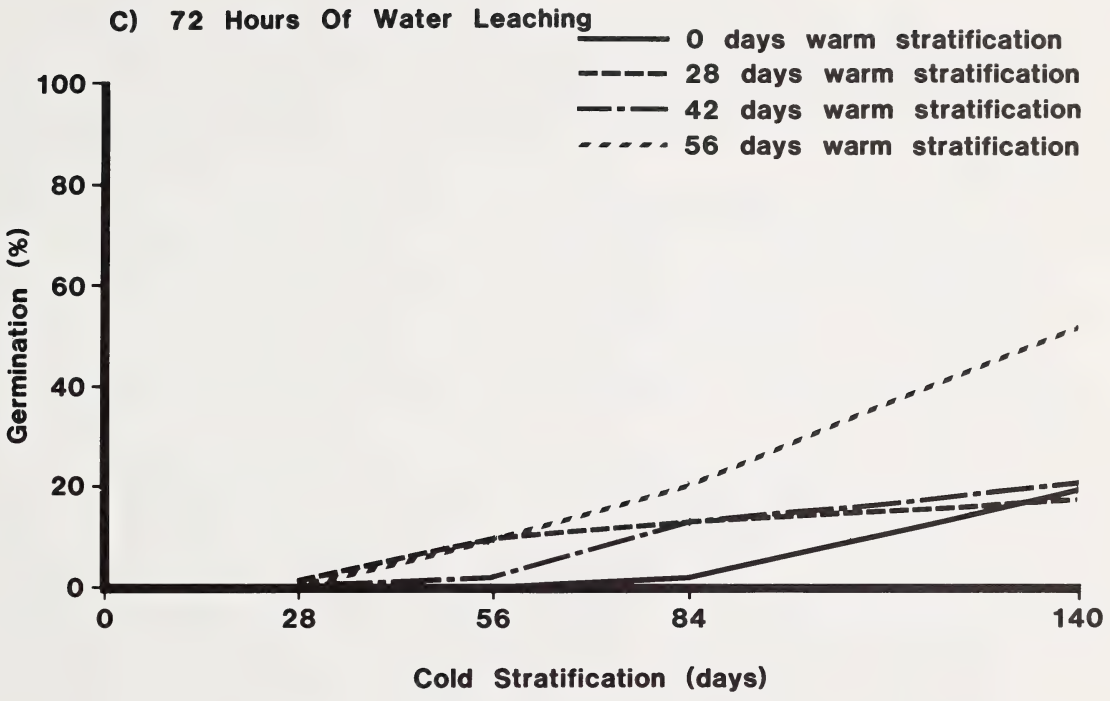
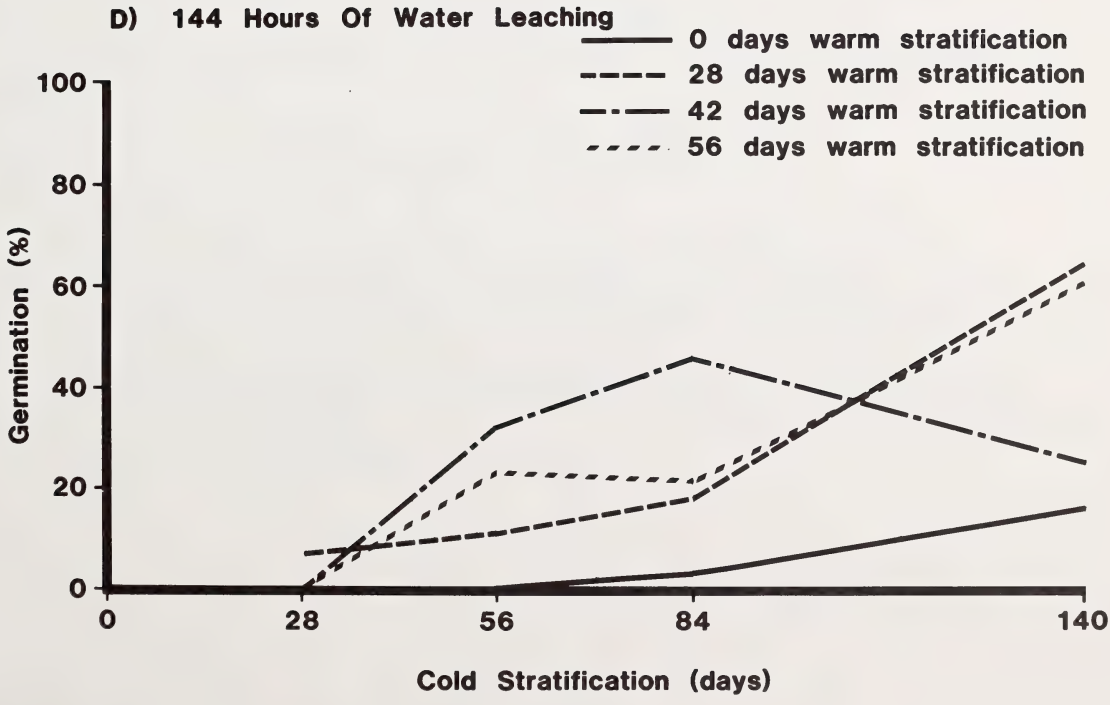

GERMINATION IN ROSA ACICULARIS
A) 0 Hours Of Water Leaching
0 days warm stratification
28 days warm stratification
42 days warm stratification
56 days warm stratification
Germination (%)
100
80
60
40
20
0
0
28
56
84
140
Cold Stratification (days)
B) 24 Hours Of Water Leaching
0 days warm stratification
28 days warm stratification
42 days warm stratification
56 days warm stratification
Germination (%)
100
80
60
40
20
0
0
28
56
84
140
Cold Stratification (days)

FIGURE 5 (continued)





resulted in relatively incomplete germination. Based on the experiments conducted to date, a compound pre-germination treatment of 28 to 42 days of warm stratification preceding cold stratification for a minimum of 140 days is promising for obtaining fairly high levels of germination in the species.

The results of one experiment suggest that the ripeness of the rose hips at the time of seed collection may play an important role in seed germination. The practical significance of this finding is the possibility of increasing germination by carrying out seed collections earlier than is traditional in prickly rose.

Despite evidence presented in the literature of water soluble germination inhibitors in Rosa acicularis and the utility of water leaching as a pre-germination treatment in another member of the genus, water leaching does not benefit germination or reduce the required length of cold stratification treatments for R. acicularis seeds.

5. RUBUS PARVIFLORUS

5.1 Summary Of Literature

(Updated from King 1980)

The literature on Rubus parviflorus seed pre-germination treatments is virtually non-existent. The only reference found reported "good" levels of germination with 50 minutes of acid scarification as well as with cold stratification for six months.

5.2 Seed Pre-Germination Treatment Testing

Two tests have been carried out on this species. One, a factorial experiment, used scarification, warm stratification and cold stratification as factors. The treatments employed are presented in Table 7. Additional information on methodology is presented in King, Grainger and Straka (1983). In the second, unscarified and mechanically scarified seeds were germinated without the benefit of any other pre-germination treatments.

The germination results of the first experiment are presented in Figure 6.

Maximum germination was obtained in response to 30 or 60 days of warm stratification followed by 90 or 60 days, respectively, of cold stratification (in unscarified seeds). Pre-germination treatment by mechanical scarification yielded significantly less germination than was obtianed in unscarified treatments. Scarification was not beneficial in the experiment. The effects of warm stratification were significant. Greater germination was obtained in response to 30 or 60 days of warm treatment while being suppressed by longer warm stratification periods. Cold stratification treatments had no significance. Germination was independent of those cold stratification treatments used.

In the second test, greater germination was obtained in non-scarified seeds than in mechanically scarified samples (Table 8). Additionally, the levels of germination obtained in this experiment, as compared to those discussed previously, suggest that cold stratification is necessary in R. parviflorus.

Table 7

FACTORS AND TREATMENTS IN

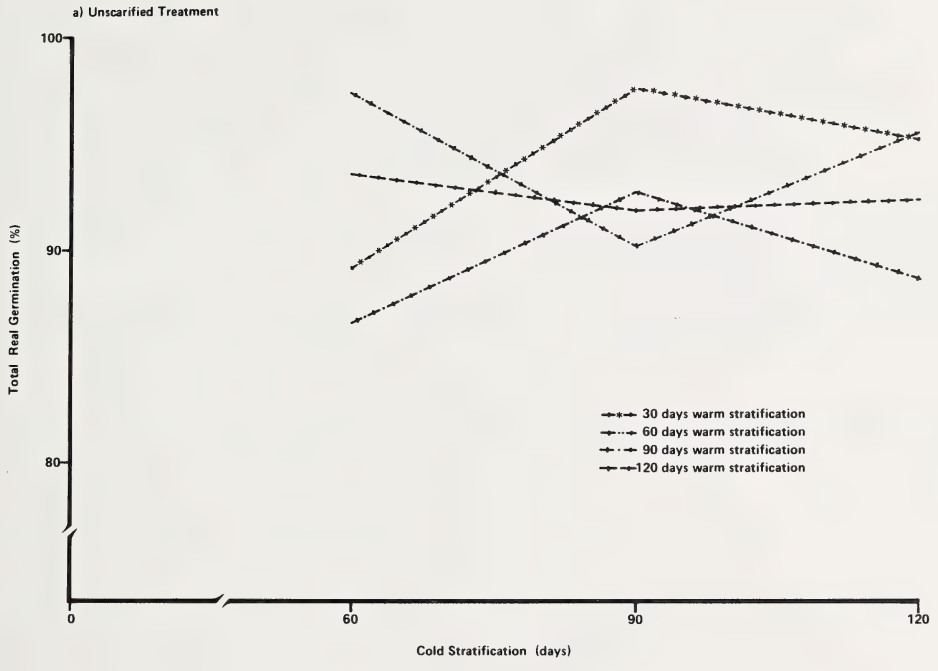
RUBUS PARVIFLORUS EXPERIMENTS (1983)

Experiment	Factor	Treatments
I	Scarification	Unscarified and (Mechanically) Scarified Seeds
	Warm Stratification	30, 60, 90, and 120 days
	Cold Stratification	60, 90, and 120 days
II	N/A	Unscarified and (Mechanically) Scarified Seeds

NOTE: In Experiment I, scarification preceded all other treatments while warm stratification was applied prior to cold stratification.

FIGURE 6

TOTAL GERMINATION IN *RUBUS PARVIFLORUS* SEEDS



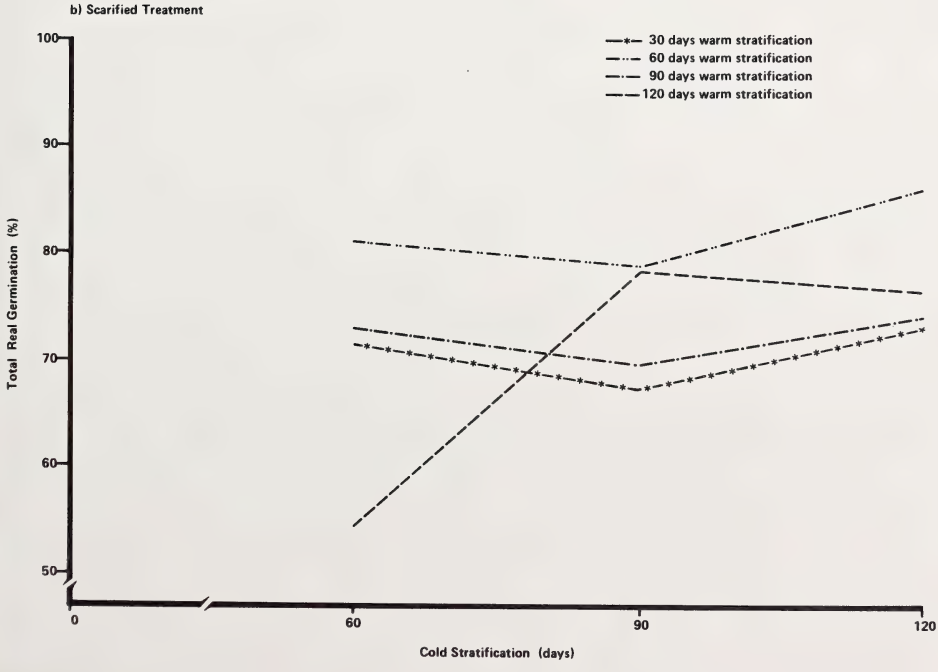


Table 8

GERMINATION IN UNSTRATIFIED

RUBUS PARVIFLORUS SEEDS (1983)

Mechanical Scarification Treatment	Germination (%)
No	29
Yes	16

5.3 Conclusions

High levels of germination were obtained in unscarified R. parviflorus seeds after pre-germination treatment with warm stratification for 30 or 60 days and cold stratification for 90 or 60 days, respectively.

Scarification was not beneficial in the experiment. Unscarified seeds which were subsequently stratified had higher germination than obtained in the respective scarified treatments. The same trend was found in unscarified and scarified seeds which were not stratified.

The effects of warm stratification were significant while those of cold stratification were not. However, the results suggest that cold stratification is necessary in the species.

6. RUBUS STRIGOSUS

6.1 Summary Of Literature
(Updated from King 1980)

Information on Rubus strigosus is contradictory on the role of the endocarp and testa in dormancy. Some references suggested water impermeability as an endocarp/seed coat-related cause of dormancy while others reported that the species is not hard seeded. An early researcher of red raspberry had hypothesized (an hypothesis frequently cited) that the endocarp restricted embryonic enlargement although there appears to be little evidence in support of this.

The occurrence of embryonic dormancy is also reported inconsistently. Some sources found that the embryo was non-dormant while others stated that treatment was required to break such dormancy.

Reported pre-germination treatments are extremely variable and may include simple sulphuric acid scarification or cold stratification, sulphuric acid scarification followed by cold stratification, sulphuric acid scarification followed by cold stratification, sulphuric acid scarification followed by warm stratification preceding cold stratification, or warm stratification before cold stratification.

6.2 Seed Pre-Germination Treatment Testing

A factorial experiment has been carried out on a single seed lot of Rubus strigosus. The factors were scarification, warm stratification and cold stratification. The treatments used in the experiment are summarized in Table 9. Complete information on the experimental methodology is presented in King, Grainger and Straka (1983).

An associated test was carried out, using mechanical scarification treatments in unstratified seeds (Table 9). King, Grainger and Straka (1983) contains further information on the methodology.

The results of the first experiment are presented in Figure 7.

Maximum germination across scarification treatments was obtained in response to warm stratification for 120 days followed by cold stratification for 90 days. The germination of unscarified red raspberry seed was significantly greater than in scarified treatments. The removal of a portion of the seed cover is not a beneficial pre-germination treatment. Warm stratification had a significant effect on germination. Germination was proportional to the duration of the warm stratification treatment with the greatest levels being obtained in response to 120 days of warm stratification. Longer periods of

Table 9

FACTORS AND TREATMENTS IN

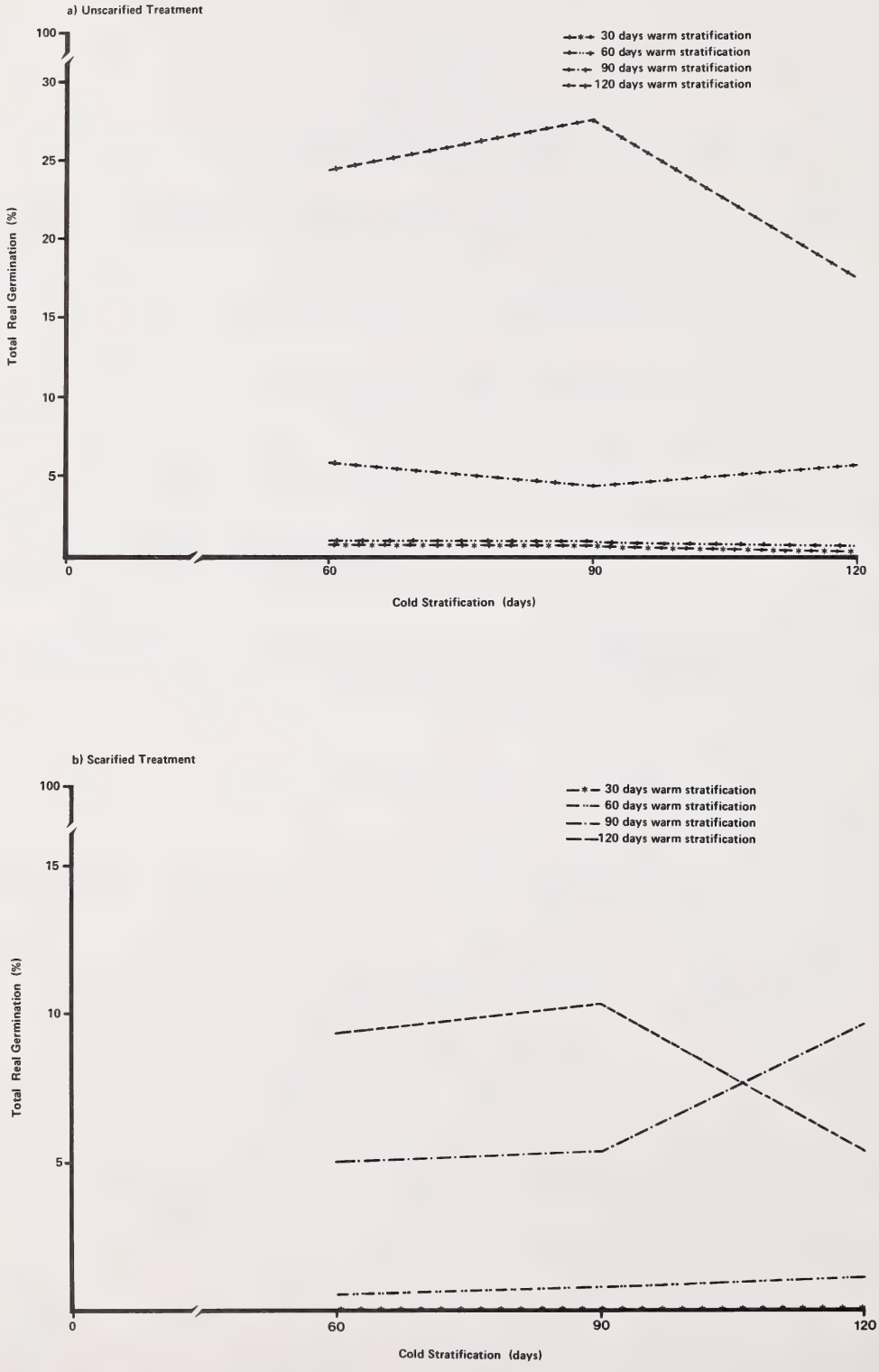
RUBUS STRIGOSUS EXPERIMENTS (1983)

Experiment	Factor	Treatments
I	Scarificaiton	Unscarified and (Mechanically) Scarified Seeds
	Warm Stratification	30, 60, 90, and 120 days
	Cold Stratification	60, 90, and 120 days
II	N/A	Unscarified and (Mechanically) Scarified Seeds

NOTE: In Experiment I, scarification preceded all other treatments while warm stratification was applied prior to cold stratification.

FIGURE 7

TOTAL GERMINATION IN *RUBUS STRIGOSUS* SEEDS



warm stratification than used in this experiment may have yielded even higher numbers of germinants.

Germination was independent of the cold stratification treatments employed in the experiment. Increasing the cold stratification period for longer than 30 days did not result in greater germination.

In the allied experiment, scarification caused depressed germination levels in unstratified seeds (Table 10). The results suggest that the seed coat is not likely impermeable to water or gases and raises further doubt about the mechanical resistance hypothesis. When the maximum germination from this and the preceding experiment are compared, the role of the embryo in R. strigosus seed dormancy appears to be uncertain.

Subsequent to the experiments described above, an embryo excision test was carried out. In the trial, entire seeds and excised embryos were placed in a germinator. Germination was counted daily until 21 days had elapsed. See Appendix 1 for further information on methodology.

The results of this test are illustrated in Figure 8. Dormancy in this seed lot of R. strigosus would appear to be largely a function of the properties of the seed coat. However, a portion of the excised embryos were dormant as 37 percent failed to germinate. It may be inferred that a treatment for embryonic dormancy, such as cold stratification, is necessary.

The final test carried out to date on the species examined water uptake in unscarified and scarified seeds of three origins. As illustrated in Figures 9-11, water uptake is rapid in both unscarified and scarified seeds, seeds are fully imbibed within two to four days and the differences

Table 10

GERMINATION IN UNSTRATIFIED

RUBUS STRIGOSUS SEEDS (1983)

Mechanical Scarification Treatment	Germination (%)
No	18
Yes	1

FIGURE 9

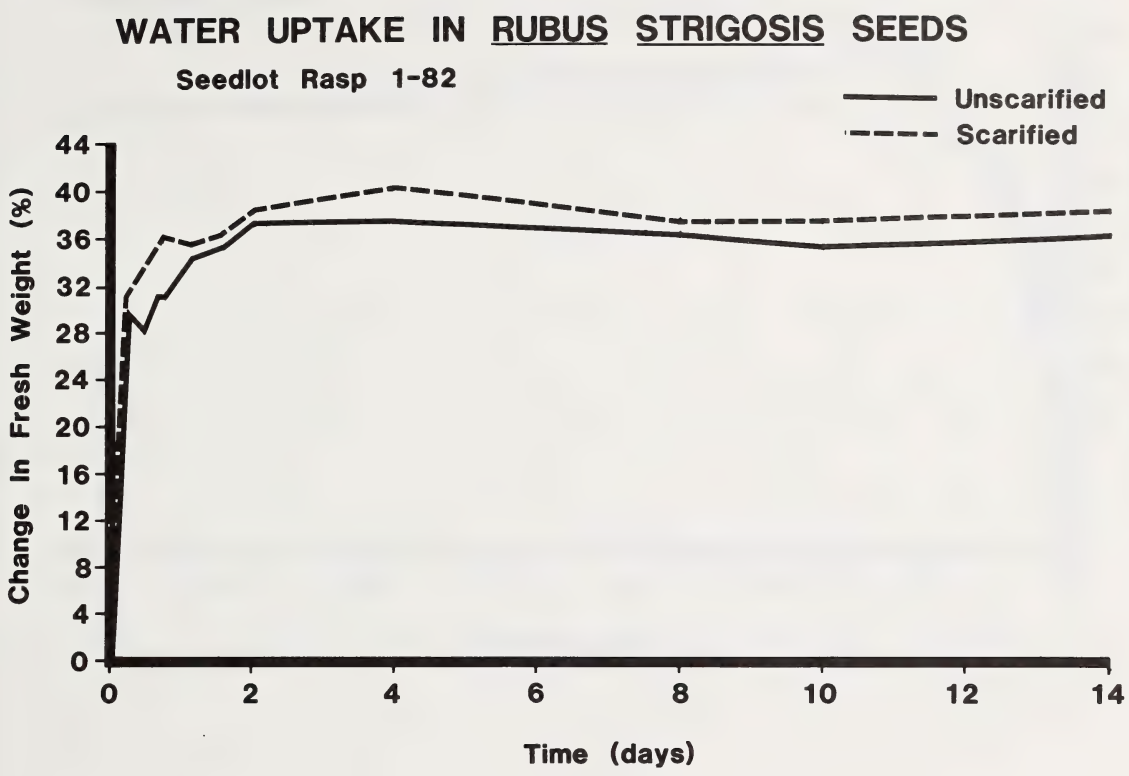


FIGURE 8

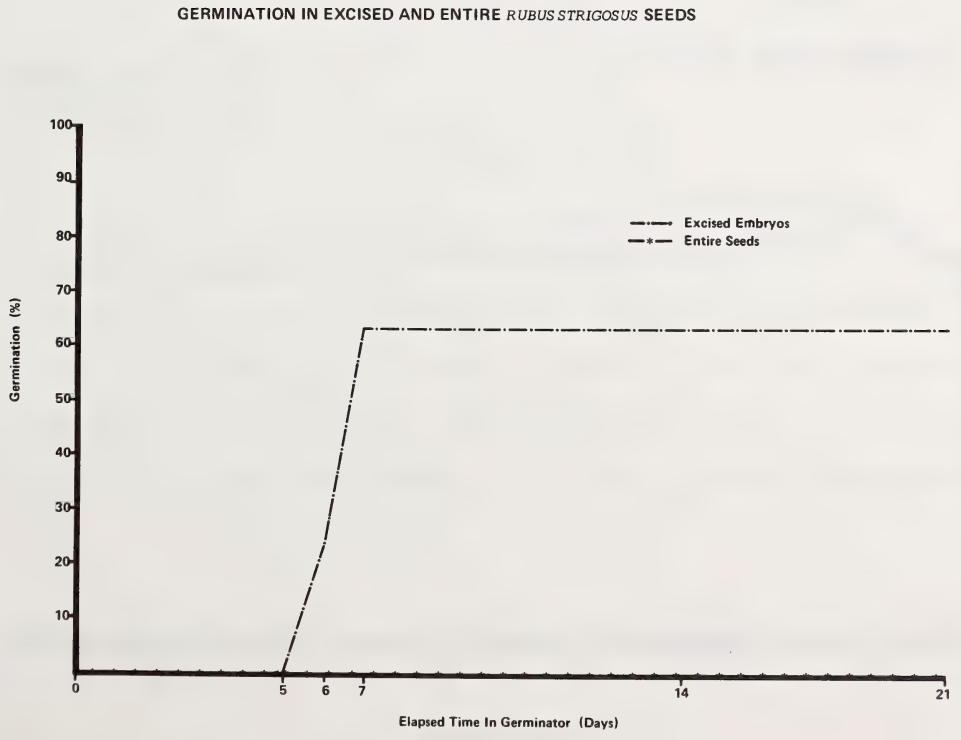


FIGURE 10

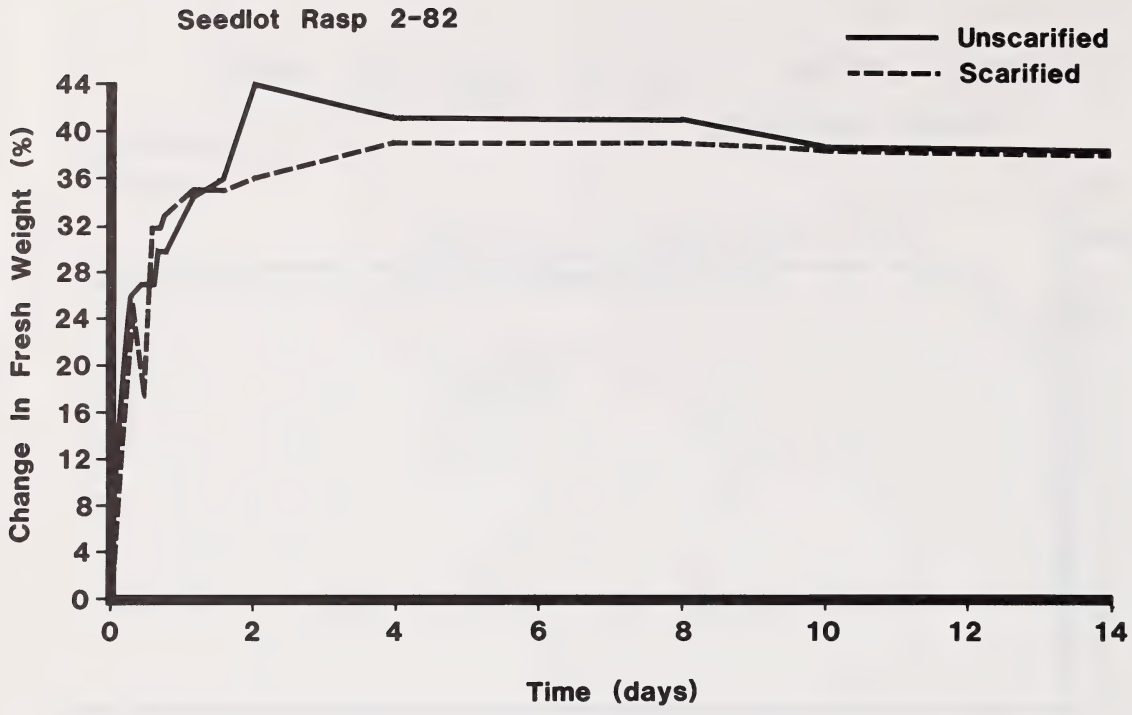
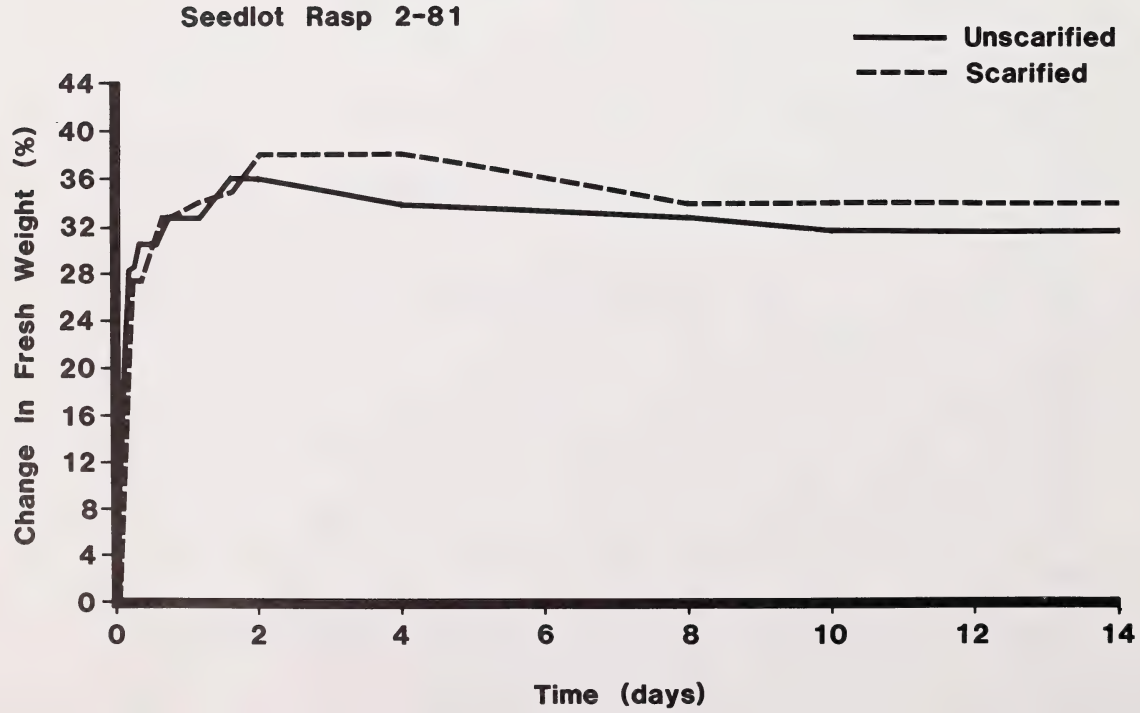


FIGURE 11



in the change of fresh weight among scarification treatments are not appreciable. The endocarp and testa of red raspberry seed are not impermeable to water.

6.4 Conclusions

Among the seed lots of R. strigosus tested, dormancy appears to be largely associated with the properties of the seed coverings although the condition of the embryo is an additional contributory factor. The endocarp and testa are not impermeable to water and it is doubtful that they are impermeable to gases or restrict enlargement of the embryo.

To date, an effective pre-germination treatment has not been achieved. Maximum germination obtained has been 28 percent in unscarified seeds in response to a dual treatment of 120 days of warm and 90 days of cold stratification.

7.0 SORBUS SCOPULINA

7.1 Summary Of Literature

(Updated from King 1980)

Information on the species is limited and difficult to evaluate because of its lack of germination data. Sorbus scopulina exhibits extreme dormancy. Pre-germination treatments reported include cold stratification, warm stratification preceding cold stratification, acid scarification preceding cold stratification, and gibberellic acid soak preceding cold stratification.

7.2 Seed Pre-Germination Treatment Testing

A factorial experiment has been carried out on a single seed lot of Sorbus scopulina. Fruit ripeness, warm stratification, and cold stratification were used as factors. The experimental treatments are summarized in Table 11. Additional information on the methodology employed is given in Appendix 1.

The total germination results obtained are presented in Figure 12.

Maximum germination of 34 percent was obtained in the experiment. This was in response to 90 days of warm stratification followed by 150 days of cold stratification, in seed from "fully ripe" collections.

The effect of ripeness treatments was significant. Greater germination was obtained in "fully ripe" treatments than with "not fully ripe". There would be no benefit from early fruit collection in this species.

Warm stratification treatments significantly affected germination. The greatest germination was in response to 90 days with germination suppressed when warm stratification was used for shorter or longer periods. The decrease in germination in this experiment with the 120 and 150 day warm stratification treatments may be attributed to microbial damage to the embryo.

The cold stratification effect was significant. Total germination was proportional to the duration of the cold stratification treatment. However, cold stratification alone gave relatively incomplete germination.

7.3 Conclusions

In S. scopulina collection of fruits before they are fully ripe will result in suppressed germination levels. Maximum germination was in response

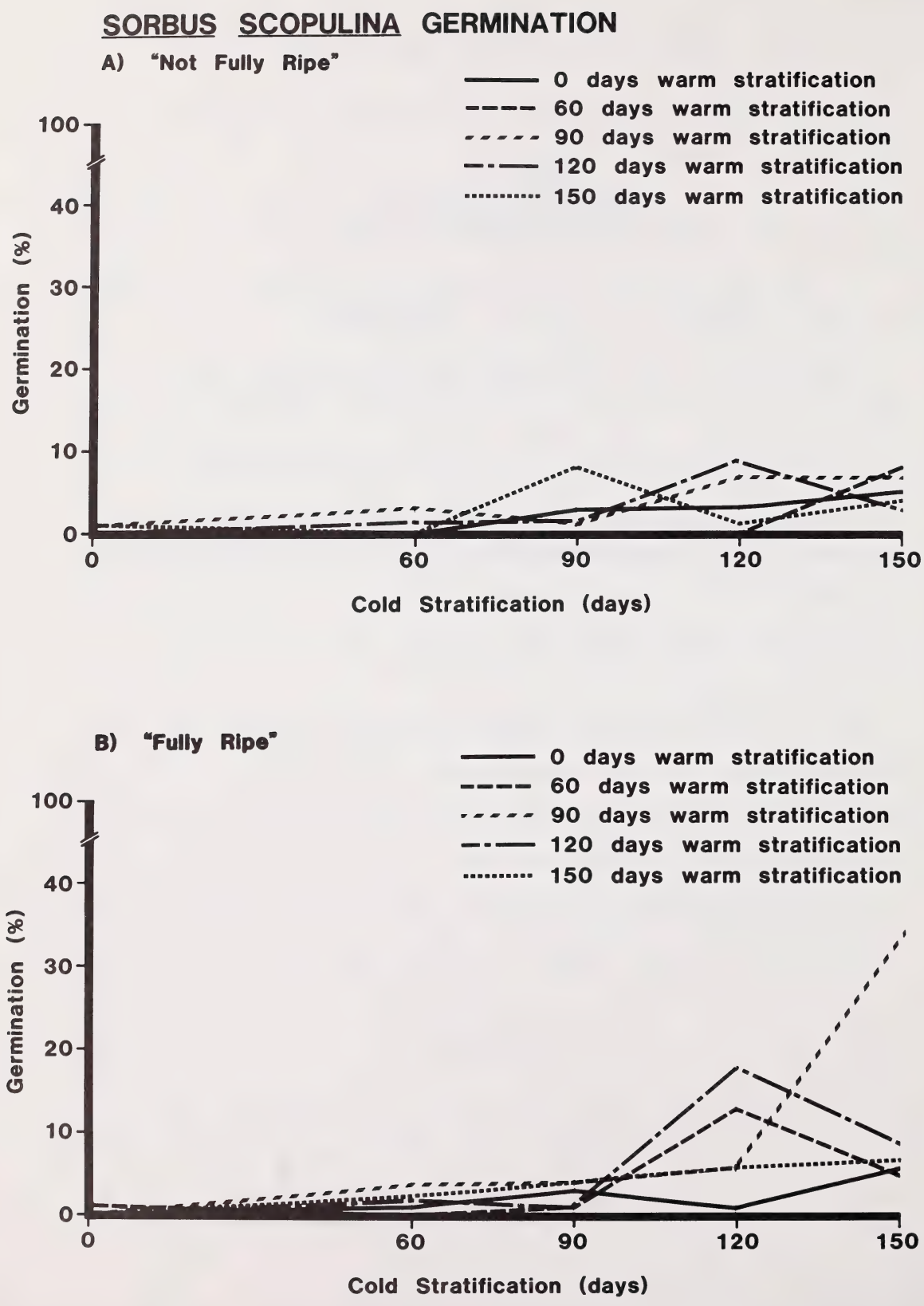
Table 11

FACTORS AND TREATMENTS IN

SORBUS SCOPULINA EXPERIMENT (1984)

Factor	Treatments
Ripeness	"Not Fully Ripe" and "Fully Ripe Seed Collection"
Warm Stratification	0, 60, 90, 120, and 150 days
Cold Stratification	0, 60, 90, 120, and 150 days

FIGURE 12


SORBUS SCOPULINA GERMINATION
A) "Not Fully Ripe"
0 days warm stratification
60 days warm stratification
90 days warm stratification
120 days warm stratification
150 days warm stratification
Germination (%)
100
40
30
20
10
0
0
60
90
120
150
Cold Stratification (days)
B) "Fully Ripe"
0 days warm stratification
60 days warm stratification
90 days warm stratification
120 days warm stratification
150 days warm stratification
Germination (%)
100
40
30
20
10
0
0
60
90
120
150
Cold Stratification (days)

to 90 days of warm stratification and 150 days of cold stratification. The species requires a combination of warm and cold stratification to achieve an appreciable level of germination.

8. SUMMARY AND FUTURE RESEARCH

8.1 Amelanchier alnifolia

In the single A. alnifolia test carried out to date, a high level of germination was attained with 150 days of cold stratification. The potential use of leaching as a supplemental pre-germination treatment is promising. Future research may deal with this factor as well as variability in dormancy and germination response among seed origins.

8.2 Elaeagnus commutata

Seed dormancy in three origins tested was entirely due to the properties of the seed coverings while the embryos were non-dormant. A moderate amount of germination can be obtained by leaching with tap water for 96 hours. It does not appear that germination can be further increased by varying leaching treatment although it appears that the levels obtained to date may, in part, be due to the germination testing conditions. Further investigation will examine this. Other means of shortening pre-germination treatment time may also be pursued.

8.3 Rosa acicularis

To date, the stratification requirements in a single seed lot have been refined. This information will be utilized in further testing of ripeness effects and in studies on the variability in dormancy and germination response among seed origins.

8.4 Rubus parviflorus

High levels of germination have been obtained in unscarified seeds using sequential warm and cold stratification. In the experimental lot there was no benefit from scarification and it does not appear that hard seed was a cause of dormancy. Germination was independent of the cold stratification treatments used in the trail although it appears that an undefined minimum cold stratification period is necessary. No further investigation of this species is currently planned.

8.5 Rubus strigosus

Dormancy in seeds tested was largely associated with the properties of the seed coverings although the condition of the embryo is also a contributory factor. Impermeability of the endocarp and/or testa to water is not a cause of dormancy and it is doubtful that mechanical resistance to embryonic enlargement and impermeability to gases are. Further work is required on confirming the dormancy mechanisms and identifying the pre-germination treatments required to obtain consistently high levels of germination.

8.6 Sorbus scopulina

The species appears to require a combination of warm and cold stratification to achieve an appreciable level of germination. In the experiment reported, a maximum of 34 percent germination was obtained in "fully ripe" seed in response to 90 days of warm stratification followed by 150 days of cold stratification. Further research on this species is required to increase germination levels.

APPENDIX 1

SUMMARY OF EXPERIMENTAL METHODOLOGY (1984)

Species	Seedlot(s)	Seed Collection		Seed Storage		Treatments	Germination Testing	Comments
		Date	Origin	Moisture Content (%)	Temperature (°C)			
Amelanchier alnifolia	RB SAS 1-82	3, 4/9/82	T 57 - R 9 - W6M	7.5	0	i) Warm Stratification Temperature: 24°C ii) Cold Stratification Temperature: 5°C iii) Leaching: carried out at room temperature in stoppered flasks on a wrist action shaker Other details as described in text.	i) Test Duration: 42 days ii) Temperature: 20/30°C (16/8 hrs) iii) Light: none iv) Relative Humidity: 80 - 90% v) Medium: sand vi) Frequency Of Counts: weekly	All germination is expressed as live germination. Viability is based on TZ testing. A seedling considered as germinated met the criteria for normal shrub seedlings of the A.O.S.A. (1978).
Elaeagnus commutata	WOL 1-81	26/9/81	T 39 - R 15 - W4M	5.8	0	Details as described in text.	i) Test Duration: 42 days ii) Temperature: 20/30°C (16/8 hrs) iii) Light: none iv) Relative Humidity: 80 - 90% v) Medium: paper vi) Frequency Of Counts: daily	All germination is expressed as live germination. Viability is based on TZ testing. A seedling considered as germinated met the criteria for normal shrub seedlings of the A.O.S.A. (1978).
	WOL 2-81	11/10/81	T 51 - R 26 - W4M	6.5	0			
	WOL 3-81	13/11/81	T 13 - R 28 - W4M	6.8	0			
Rosa acicularis	RB PRI 2-82	29/9/82	T 57 - R 9 - W6M	7.0	0	i) Warm Stratification Temperature: 24°C ii) Cold Stratification Temperature: 5°C iii) Leaching: carried out at room temperature in stoppered flasks on a wrist-action shaker Other details as described in text.	i) Test Duration: 63 days ii) Temperature: 20°C (constant) iii) Light: 16 hours per day iv) Relative Humidity: 80 - 90% v) Medium: vermiculite vi) Frequency Of Counts: weekly	All germination is expressed as live germination. Viability is based on TZ testing. A seedling considered as germinated met the criteria for normal shrub seedlings of the A.O.S.A. (1978).
Rubus strigosus i) Embryonic Dormancy	RB RASP 2-82	16/8/82	T 57 - R 9 - W6M	6.5	0	Details as described in text.	i) Test Duration: 21 days ii) Temperature: 20/30°C (16/8 hrs) iii) Light: during high temperature period iv) Relative Humidity: 80 - 90% v) Medium: sand vi) Frequency Of Counts: daily	All germination is expressed as live germination. Viability is based on TZ testing. A seedling considered as germinated met the criteria for normal shrub seedlings of the A.O.S.A. (1978).
ii) Water Imbibition	RB RASP 1-82	14/8/82	T 44 - R 17 - W5M	6.0	0	i) Scarification: mechanical ii) Imbibition: samples placed into distilled water in beakers Other details as described in text.	N/A	N/A
	RB RASP 2-82	16/8/82	T 57 - R 9 - W5M	6.5	0			
	RB RASP 2-81	20/9/81	T 6 - R 4 - W5M	6.0	0			
Sorbus scopulina	RB MNT 3-81A ("not fully ripe")	21/9/81	T 4 - R 3 - W5M	5.8	0	i) Warm Stratification Temperature: 24°C ii) Cold Stratification Temperature: 5°C	i) Test Duration: 63 days ii) Temperature: 20/30°C (16/8 hrs) iii) Light: none iv) Relative Humidity: 80 - 90% v) Medium: sand vi) Frequency Of Counts: weekly	All germination is expressed as live germination. Viability is based on TZ testing. A seedling considered as germinated met the criteria for normal shrub seedlings of the A.O.S.A. (1978).
	RM MNT 3-81 ("fully ripe")	21/9/81	T 4 - R 3 - W5M	6.2	0			

LITERATURE CITED

Association of Official Seed Analysts. 1978. Rules for testing seed. Journal of Seed Technology. 3(3):125 pp.

King, P. 1980. Review of Seed Pretreatments Required for Germination of Candidate Native Tree and Shrub Species in the Eastern Slopes of the Rocky Mountains and Foothills of Alberta. Alberta Energy and Natural Resources, Alberta Forest Service, E.N.R. Report No. 154. Edmonton, Alberta. 56 pp.

_____. 1981. Seed Testing Project. Unpublished report, Alberta Energy And Natural Resources, Alberta Forest Service. Edmonton, Alberta. 53 pp.

King, P., Grainger, G. and Straka, A. 1983. Testing of Seed Pre-Germination Treatments for Selected Native Shrub Species. Alberta Energy and Natural Resources, E.N.R. Report No. T/43. Edmonton, Alberta. 80 pp.

REFORESTATION STUDIES AT THE JUDY CREEK TEST MINE - OVERVIEW AND PRELIMINARY RESULTS

Alan Kennedy
Esso Resources Canada Ltd.

Paper Presented at:

Revegetation Methods for
The Mountains and Foothills

RRTAC Workshop
Held April 30 - May 1, 1984
Edmonton, Alberta

1599K

INTRODUCTION

The purpose of this paper is to give the objectives, study methods and preliminary results of the Judy Creek test mine reforestation studies. Broadly stated, the reforestation studies are designed to investigate relevant questions concerning reforestation techniques on mined lands in a mountain/foothills ecosystem. Based on this general idealogy four specific study objectives were developed for conduct at the Judy Creek test mine. The four studies conducted at the test mine are:

1) The effects of soil depth replacement over till on reforestation;
2) The effects of seeded agronomic vegetation cover on tree seedling establishment and growth;
3) Reforestation on sites cleared but otherwise undisturbed; and
4) The relationship between small mammal population dynamics and reforestation success.

The remaining text describes the study area, surface disturbance, study methods, as well as preliminary results on each of the studies.

STUDY AREA

The Judy Creek test mine is located within the Judy Creek North Coal Reserve approximately 56 kilometers (km) south of Swan Hills, Alberta, and 2 km east of Highway 32. The test mine is located in the NW 1/4, Section 14, Township 64, Range 10, west of the 5th meridian (Figure 1).

A total area of 17.3 hectares (ha) was cleared for test mine operations in December, 1978, of which 1.5 ha comprised the test pit itself. An additional 2 ha area (2 km in length) was cleared as an access road to highway 32.

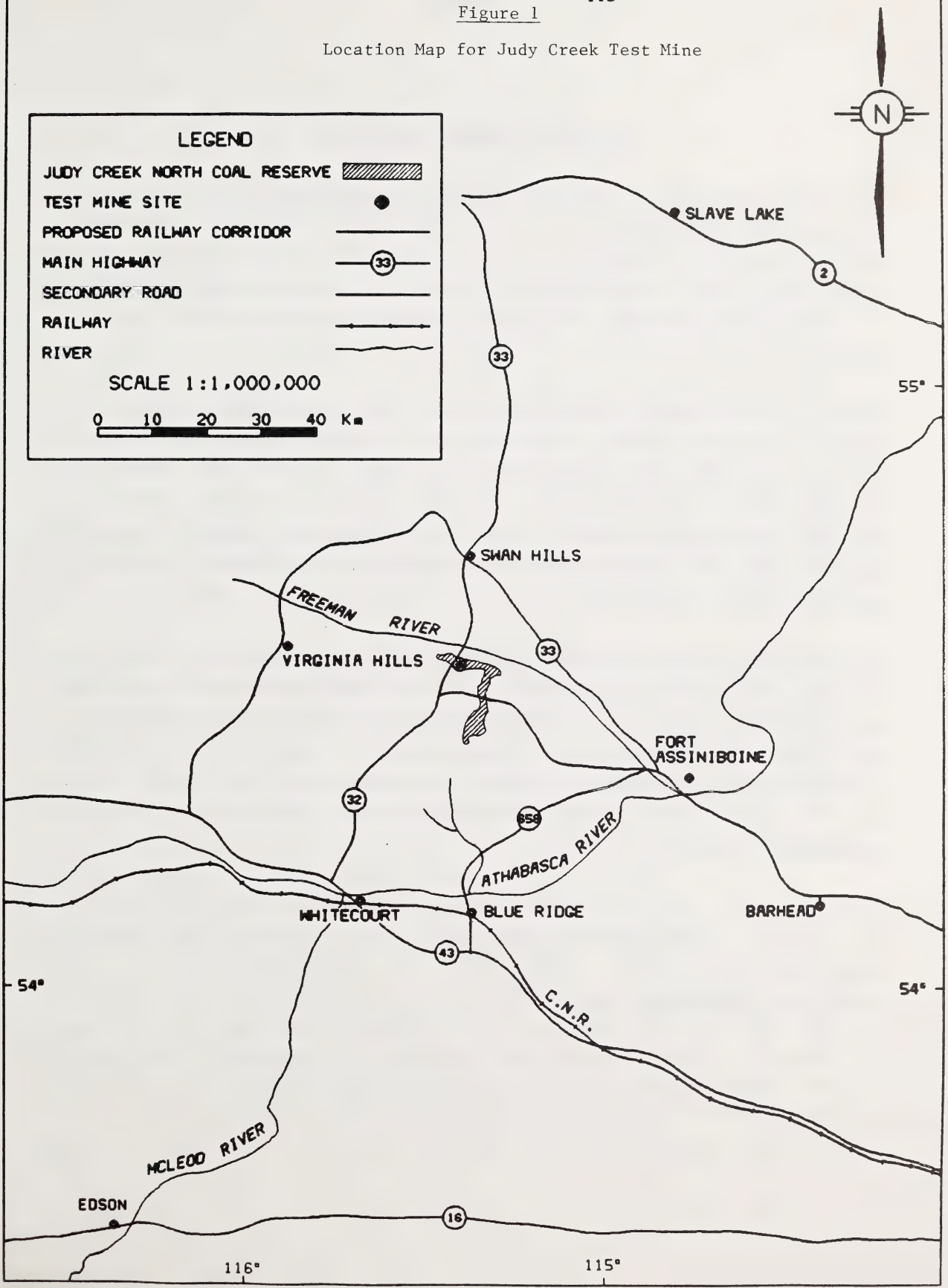
The study area is characterized regionally by warm summers and cold winters. Mean daily temperatures vary from a low of -17 degrees C (in January) to a high of 20 degrees C (in July). Average annual total precipitation is about 53 centimeters of which approximately 33% is received as snowfall. The prevailing wind directions are west and northwest.

The test mine lies at the western edge of the western plains physiogeographic region, in what is termed the Rocky Mountain Foothills area of Alberta. Elevations in the area range from 600 m on the Freeman River to over 1400 m in the Swan Hills. The hydrography of the area is dominated by the Freeman River, the Judy Creek, and the Christmas Creek; all tributaries of the Athabasca River.

Forest cover on the study area is dominated by stands of white spruce (Picea glauca) and lodgepole pine (Pinus contorta). Spruce and pine occur as a mosaic of even-aged pure stands, depending on slope; or as stands of various mixtures of pine and spruce mixed-wood forests of either pine or spruce and aspen (Populus tremuloides) or balsam poplar (Populus balsamifera). Shrublands occur as clumps of mainly willow (Salix sp.) along riparian sites, or to a minor extent on roadways and access clearings.

Figure 1

Location Map for Judy Creek Test Mine



OVERVIEW OF SURFACE DISTURBANCE

Test mining operations at the site began in late December 1978 and included: clearing timber and vegetation; separate removal and stockpiling of overburden materials and coal; backfilling and recontouring the pit; and replacing surface soils. For further details on test mine construction, coal sampling, and backfilling operations the reader is referred to Esso Minerals Canada, (1979).

After the access road had been built and the site cleared, surface soil to a depth of 70 cm was removed with scrapers from the test pit and from the till, shale and coal stockpile areas, and was stockpiled. Scrapers then removed the till and shale from the test pit and piled these in separate stockpiles. After the coal had been removed, the till and shale were replaced on the pit in 0.3 m lifts in the same sequence in which they had been removed. Each lift was compacted by scrapers and dozers before the next lift was placed.

After the pit had been backfilled and compacted, the surface was recontoured to slopes of less than six percent in order to minimize erosion and to conform to the surrounding terrain. Then, 70 cm of stockpiled surface soil was placed on the recontoured surface and on those portions of the coal, shale and till stockpile areas that were not reserved for reclamation plots. Depths of 70 cm, 30 cm and 0 cm were placed where appropriate on these stockpile areas to accommodate the reclamation plots.

By February 28, 1979, the Alberta Land Conservation and Reclamation Council had approved the completed backfilling, soil replacement and cleanup operations at the site. Consequently, the reforestation portion of the program was implemented in May 1979.

STUDY METHODS

Effects of Soil Replacement Over Till on Reforestation

This study consists of nine 20 m X 40 m plots numbered 1.1 through to 1.9 (Figure 2). Different depths of surface soil were placed on the till at the conclusion of mining operations in 1979. Analysis of the till indicated that this material was suitable for plant growth (Esso Minerals Canada, 1979) but no information was available on its relative growth potential. Study plots 1.1, 1.2 and 1.3 received 70 cm (27.5 inches) of surface soil; plots 1.4, 1.5 and 1.6 received 0 cm of surface soil; and plots 1.7, 1.8 and 1.9 were topsoiled with 30 cm (11.8 inches) of surface soil. Each plot was then planted with a complete grass/legume seed mix. A description of the seed mix and broadcast rate is given in Table 1. Based on previous soil tests (Esso Minerals Canada, 1979), fertilizer (23-23-0) was applied to each plot at a rate of 160 kg/ha.

Within each of the study plots 36 well spaced (2.4 m to 2.7 m intervals) lodgepole pine seedlings were planted. Planting occurred on June 1 and 2 1979 using both V-bar (2/3 of trees) and shovel mattock (1/3 of trees) techniques. Seedlings were all one year old at planting and were obtained from a local supplier (Blue Ridge Lumber (1981) Ltd. Whitecourt, Alberta). Twenty-four pine seedlings per plot (n = 234) were permanently marked using a wooden stake with metal identification tag. An assessment of survival, condition, and growth was made on each marked tree annually from 1979 to 1983.

Effects of Seeded Agronomic Cover on Tree Establishment and Growth

This study consists of twenty-four 12.5 m X 30 m plots numbered 1 to 24 (Figure 3). All plots are situated on the backfilled test pit. The study treatments were constructed in a randomized block design. Block 1.0 contains those plots (13-24) on the upslope, mesic portion of the study area and block 2.0 contains those plots (1-12) on the downslope, mesic-moist portion. Within each block, two different grass/legume seed mixes were applied, each at a

Figure 2

Soil Replacement Study Plot Plan

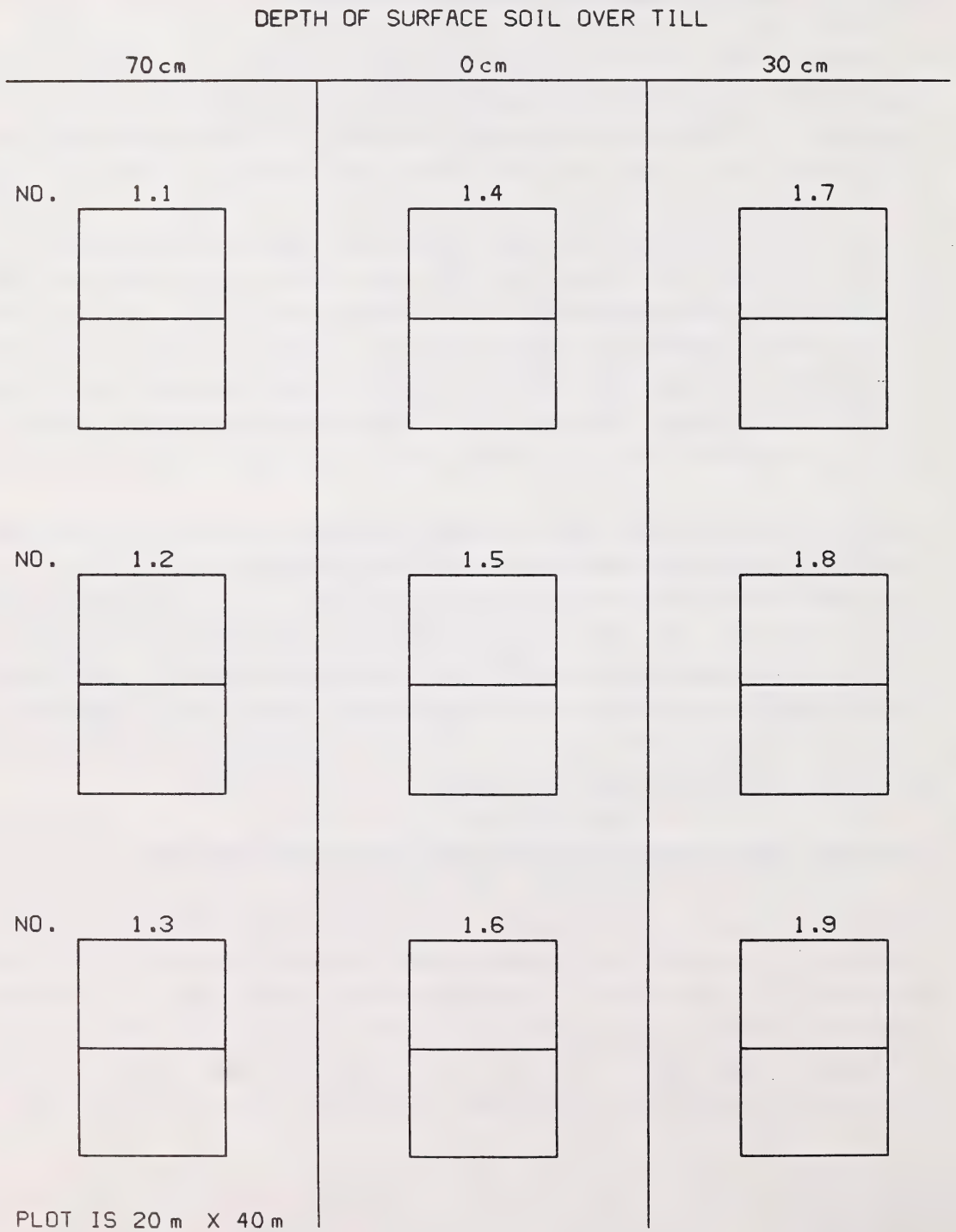


Table 1

Seed Mix One, a Complete General Grass (Sod/Bunchgrass) and Legume Seed Mix for Moist to Dry Areas

Species	Variety	Percent of Mix (by wt.)	Broadcast Seeding (kg/ha)	Features and Tolerances
Grasses				
Canada bluegrass	Common	20	6.0	Low maintenance, tolerance to grazing, aggressive, drought tolerant
Creeping red fescue	Boreal	15	4.5	Tolerant to grazing, good seedling vigor, sod forming
Slender wheatgrass	Revenue	10	3.0	Strong root system for erosion control
Crested wheatgrass	Fairway	15	4.5	Good seedling vigor, can withstand traffic
Timothy	Climax	10	3.0	Rapid establishment, fibrous roots
Smooth brome	Carlton	10	3.0	Long-lived, sod forming
Legumes				
Alfalfa	Drylander	10	3.0	Superior winter hardiness, drought resistant
Red clover	Altaswede	10	3.0	Short-lived, winter hardy, acid tolerant
		100	30.0	

1599K

different rate of seeding. In block 1.0 seed mixtures 1 and 3 were used; these mixtures are suited to site conditions that range from mesic to dry. Seed mixtures 2 and 4 were applied to the downslope block (2.0) and are suited to moist to wet conditions. Tables 2, 3 and 4 give the composition of each seed mixture applied to the study plots. In each block a seed mixture (mix 1 in block 1.0 and mix 2 in block 2.0) containing sod and bunch-forming grass species generally recommended for erosion control was seeded. However, the grasses used in seed mixtures 3 and 4 (mix 3 in block 1.0 and mix 4 in block 2.0) are only bunch-forming and are less likely to provide a dense competitive cover (Watson et al 1980).

After 70 cm of surface soil had been replaced on the study plots all seed mixtures were broadcast using hand-operated cyclone seeders. Seed mix No. 1 (Table 1) was applied to three plots in block 1.0 at 15 kg/ha and three others at 30 kg/ha. The remaining six plots were treated similarly with seed mix No. 3 (Table 8). Seed mixes No. 2 (Table 2) and No. 4 (Table 4) were applied similarly to block 2.0. Figure 3 shows the seeding and broadcast regime for the study treatments. All plots were fertilized in the same manner with N-P-K (23-23-0) at 160 kg/ha.

Twenty-three lodgepole pine and 23 white spruce seedlings were planted in alternating equally spaced rows in each plot. The trees were planted June 2, 1979 using both V-bar (2/3 of trees) and shovel mattock (1/3 of trees) techniques. Lodgepole pine seedlings were one year old and white spruce seedlings were two years old at time of planting.

Six lodgepole pine (n = 144) and six white spruce (n = 144) seedlings were permanently marked for study in each plot.

Reforestation On Sites Cleared but Overwise Not Disturbed

This study consists of six 20 m x 20 m plots situated on cleared but otherwise undisturbed sites. Plots 1, 2 and 3 are on an upslope mesic location in the southeast corner of the test mine site. Plots 4, 5 and 6 are in the northwest corner of the site, in a downslope relatively moist location.

Figure 3

Plot Plan for Study of Effects of Seed Mixtures on Reforestation

GRASS SEEDING REGIME

	PLOT	SEED MIX NO.	BROADCAST SEEDING RATE (kg/ha)
BLOCK 1.0			
	1,6,12	2	30
	3,7,9	2	15
	4,5,11	4	30
	2,8,10	4	15
BLOCK 2.0			
	13,20,23	1	30
	16,18,24	1	15
	14,17,22	3	30
	15,19,21	3	15

DOWNSLOPE END

1	2	3	4
5	6	7	8
9	10	11	12
13	14	15	16
17	18	19	20
21	22	23	24

UPSLOPE END

* EACH PLOT IS 12.5 m X 30 m

Table 2

Seed Mix Two, a Complete Grass (Sod/Bunchgrass)
and Legume Seed Mix for Moist to Wet Areas

Species	Variety	Percent of Mix (by wt.)	Broadcast Seeding (kg/ha)	Features and Tolerances
Grasses				
Creeping bentgrass	Emerald	10	3.0	Stoloniferous, prefers moist areas
Creeping red fescue	Boreal	25	7.5	Deep rooted, strong rhizomes
Reed canarygrass	Frontier	25	7.5	Flood tolerant, rapid establishment
Tall wheatgrass	Orbit	20	6.0	Rhizomatous, adapted to moist areas
Timothy	Climax	5	1.5	Rapid establishment, fibrous roots, moisture tolerant
Legumes				
Alsike clover	Aurora	10	3.0	Flood tolerant, superior winter hardiness, acid tolerant
Red clover	Altaswede	5	1.5	Winter hardy, short-lived, acid tolerant
		100	30.0	

1599K

Table 3

Seed Mix Three, a Grass (Bunchgrass) and Legume Seed Mix for Moist to Dry Areas

Species	Variety	Percent of Mix (by wt.)	Broadcast Seeding (kg/ha)	Features and Tolerances
Grasses				
Slender wheatgrass	Revenue	30	9.0	Strong root system for erosion control
Crested wheatgrass	Fairway	35	10.5	Good seedling vigor, can withstand traffic, not too tall
Timothy	Climax	15	4.5	Rapid establishment, fibrous roots
Legumes				
Alfafa	Drylander	10	3.0	Superior winter hardiness, drought resistant
Red clover	Altaswede	10	3.0	Short-lived, winter hardy, acid tolerant
		100	30.0	

Table 4

Seed Mix Four, a Grass (Bunchgrass) and Legume Seed Mix for Moist to Wet Areas

Species	Variety	Percent of Mix (by wt.)	Broadcast Seeding (kg/ha)	Features and Tolerances
Grasses				
Reed canarygrass	Frontier	25	7.5	Flood tolerant
Tall wheatgrass	Orbit	45	13.5	Rhizomatous, adapted to moist areas
Timothy	Climax	15	4.5	Rapid establishment, fibrous roots, moisture tolerant
Legumes				
Alsike clover	Aurora	10	3.0	Flood tolerant, superior winter hardiness, acid tolerant
Red clover	Altaswede	5	1.5	Winter hardy, short-lived, acid tolerant
		100	30.0	

Evenly spaced alternating rows of 25 lodgepole and 25 white spruce were planted on June 2, 1979. Lodgepole pine seedlings were 1 year old and white spruce seedlings were 2 years old at time of planting. All trees were planted with a V-bar. No seed or fertilizer were applied to the plots.

The number of lodgepole pine and white spruce marked for study were; four in plots 1 and 2, six in plot 3, four in plots 4 and 5 and five in plot 6.

Relationship Between Small Mammal Population Dynamics and Reforestation Success.

Small mammal populations were examined by standard live-trapping techniques. Two permanently marked trapping grids were established on the Judy Creek test mine site (Figure 4). Each grid contained 100 traps arranged in 10 rows and 10 columns with trapping stations at 15 m intervals. Each grid encompassed 2.25 ha. One Sherman live-trap (7.5 cm x 7.5 cm x 23.0 cm) was placed at each trapping station, baited with oats and peanut butter, and furnished with synthetic cotton nesting material.

The trapping schedule, by year, for the small mammal population study is given in Table 5. In 1979 (fall) and 1980 (spring and fall) trapping was conducted for 8 trap-days during May and September. Small mammal trapping during 1981, 1982 and 1983 was conducted for ten consecutive days. This increase in trapping effort facilitated the capture of a more representative percentage of the meadow vole population.

All traps were examined for small mammal captures twice each day between 07:00 to 09:00 hrs. and 17:00 to 19:00 hrs. Each captured animal was given an individual number designated by toe clipping and a metal ear tag before it was released at the point of capture. The following data were recorded for each captured animal: species, identification number, physical condition (parasitism), breeding condition, sex, weight, age, location of capture (grid A, B or seismic line), and trapping station.

The following range of weights are used to standardize the age classification of the three most common small mammal species in the study:

Species	Range in Weight (grams)		
	Juvenile	Sub-Adult	Adult
Meadow Vole	0 to 14.0	14.1 to 24.0	24.1 and greater
Deer Mouse	0 to 12.0	12.1 to 18.0	18.1 and greater
Red-backed Vole	0 to 13.0	13.1 to 19.0	19.1 and greater

This classification is based on weight frequency distributions previously observed at Judy Creek and those reported elsewhere (i.e., Fuller, 1969, 1977; Morrison et al. 1954; Barbehenn, 1955).

The small mammal capture data were analysed to show species composition and known population densities on each grid. Population densities are represented by the minimum number of individuals of each species known to be alive per ha for each grid. This measure of population density is used instead of the Lincoln Index estimate because the prerequisites for the latter estimate is not met by small mammals; that is, the probability of being captured is not equal among individual animals (Krebs 1969).

Methods of Estimating Tree Survival, Growth and Condition

Estimations of tree survival, condition, growth, and assessment of causes of mortality were conducted on all reforestation plots in August 1979 and June and August of 1980, 1981 and 1983. During 1982, only tree survival and condition were evaluated during June.

Tree survival was determined through evaluation of the status of each tree (i.e. living or dead). As a method of data reduction a mean total survival value was calculated for each treatment based on the equation; total living trees per plot ÷ n trees per plot x 100.

Figure 4

Location of Small Mammal Live Trapping Grids

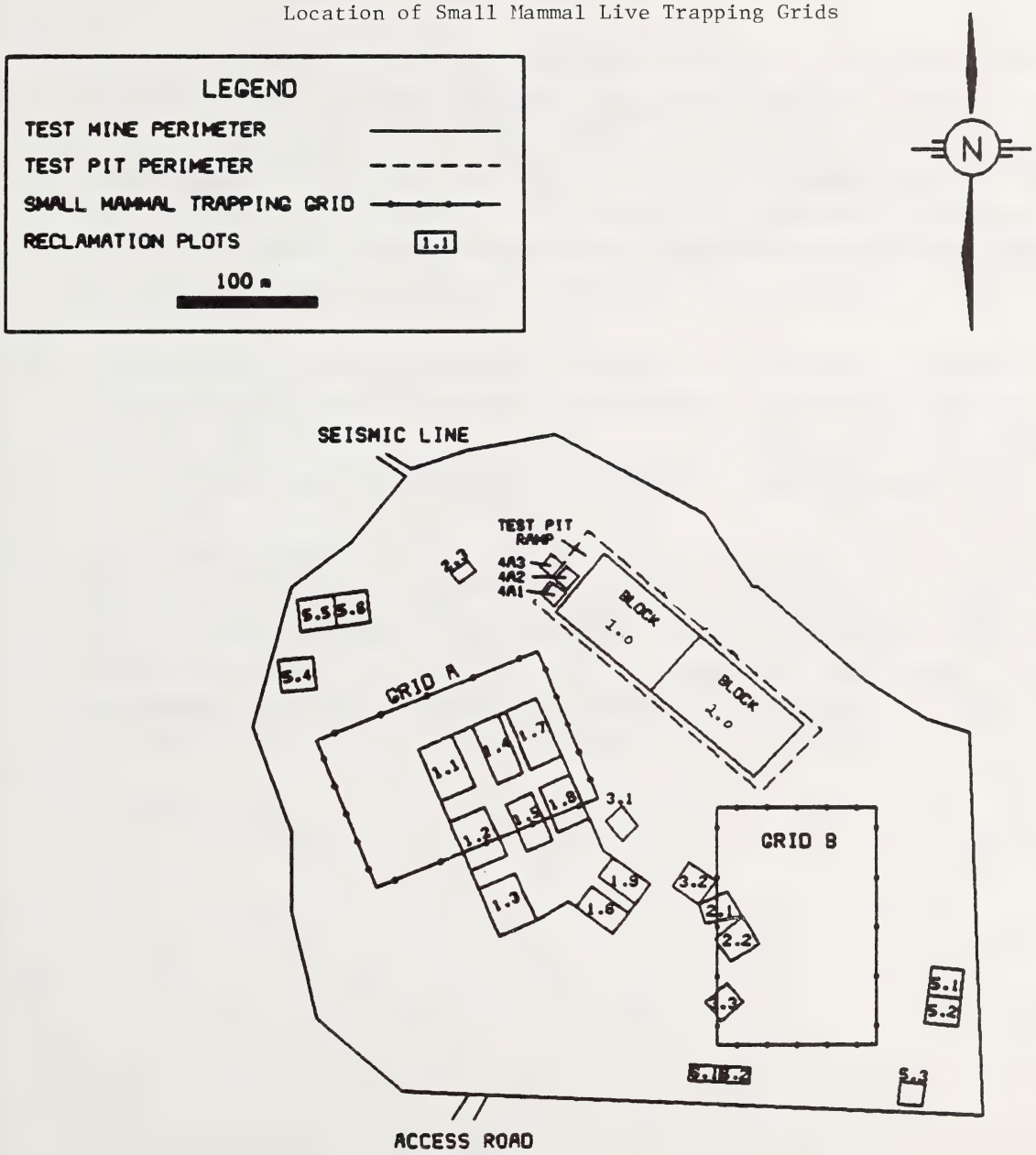


Table 5

Small Mammal Trapping Schedule, 1979-1983

Year	Season	Date	Trapping Duration (Trap-Days)
1979	Fall	79 08 30 - 79 09 05	8
1980	Spring	80 05 24 - 80 05 31	8
	Fall	80 09 07 - 80 09 13	8
1981	Spring	81 05 27 - 81 06 05	10
	Fall	81 09 05 - 81 09 14	10
1982	Spring	82 05 25 - 82 06 05	10
	Fall	82 09 07 - 82 09 17	10
1983	Spring	83 05 27 - 83 06 07	10
	Fall	83 09 06 - 83 09 16	10

Tree condition was determined through the observation of the health status of each marked tree for each treatment plot. Four condition catagories were used; 1) poor health, 2) moderate health, 3) good health, and 4) very good health. Table 6 provides the criteria for each condition classifica- tion. Determination of condition status was somewhat subjective due to a reliance on observer estimation. However the condition catagories were sufficiently large to avoid confusing or overlapping condition estimations.

An assessment of mortality was made to compliment the survival data. At each tree where appropriate a mortality note was added t the survival observation. Mortality notes were; 1) planting dead, 2) competition dead, 3) small mammal dead, 4) large mammal dead, 5) flooded dead, and 6) partial girdling alive.

Growth was recorded by measuring the height of each marked tree with a graduated meter stick. Height was considered a true indicator of growth and therefore basal diameter was not measured. Incremental growth was determined through measurement of the new vertical growth for each year. Height measurements were taken in August of 1979, 1980, 1981 and 1983.

Table 6

Criteria for Condition Evaluation of Marked Out-planted Trees

Class	Description	Criteria
1	Poor Health	- 75% or greater dead leaves on entire stem - Recovery unlikely
2	Moderate Health	- 25% or less dead leaves on entire stem - Some chlorotic leaves evident - Recovery likely
3	Good Health	- No dead leaves on entire stem - Branches full and developed - New growth evident
4	Very Good Health	- All leaves exhibit good color and rigor - Branches full and normally developed - New growth exhibited - Superior specimen

PRELIMINARY RESULTS

Data and initial interpretations from the reforestation studies have been presented in the 1983 annual report submitted to the Environment Alberta, Land Reclamation Council (in accordance with Development and Reclamation approval No. C-4-78). However, final analysis and conclusions are pending, therefore, presentation of the salient initial results is given here for discussion purposes.

Effects of Soil Replacement Depth Over Till

Figure 5 shows the relationship between soil replacement depth and tree survival. Seventy centimetres and 30 cms of soil were very similar in terms of total mean percentage survival, however, 0 cms replacement afforded less survival. A similar relationship was found between soil depth replacement treatments and total tree height (Figure 6). The 0 cm plots afforded much less growth than the 70 cm or 30 cm treatments.

Effects of Seeded Agronomic Cover on Tree Establishment and Growth

Tree Survival

Survival of lodgepole pine and white spruce are shown in Figures 7 and 8, respectively. Survival for both tree species was approximately equal in 1980, however, from 1981-1983 plots with seed mixtures one and three afforded less survival than plots with seed mixtures two and four.

Tree Growth

Total mean height of lodgepole pine and white spruce seedlings in relation to seed mixture is given in Table 7. Growth of both pine and spruce seedlings was similar in all plots from 1980-1982. In 1983 pine growth was reduced in plots with seed mixtures 3 and 4 and white spruce growth was lower in plots with seed mixtures 1 and 3.

Figure 5

Total Mean Percentage Tree Survival and Soil Depth Replacement Treatment

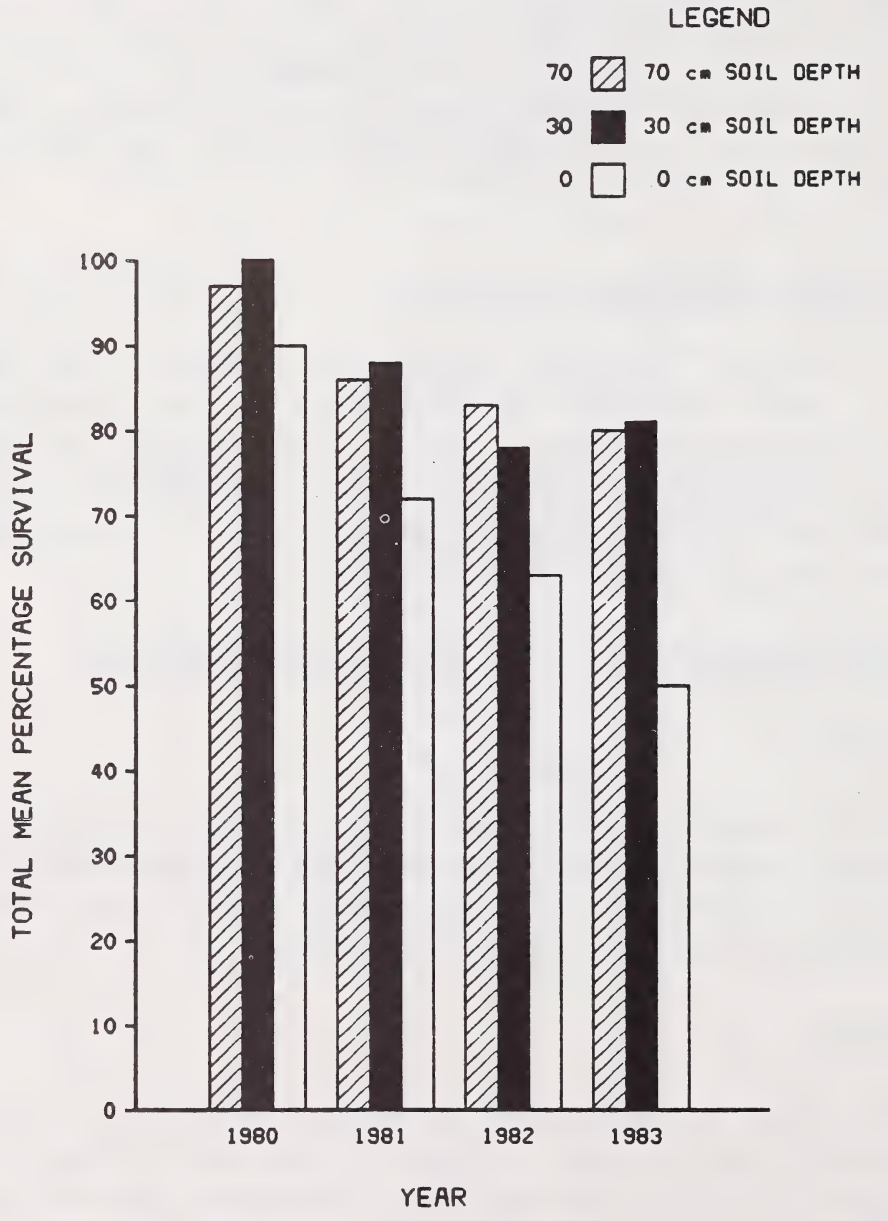


Figure 6

Total Height of Lodgepole Pine by Soil Depth Treatment

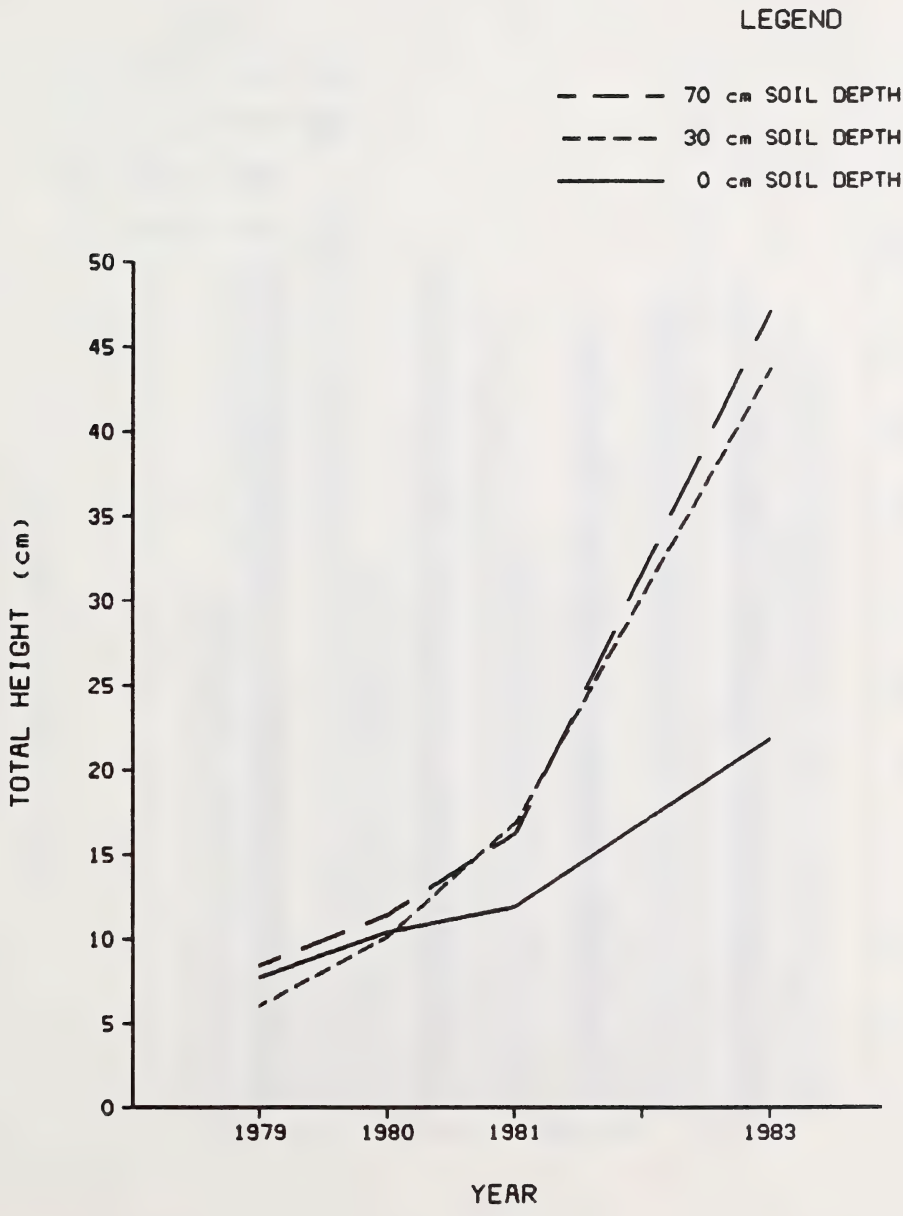


Figure 7

Total Mean Percentage Survival of Lodgepole Pine by Seed Mixture Treatment

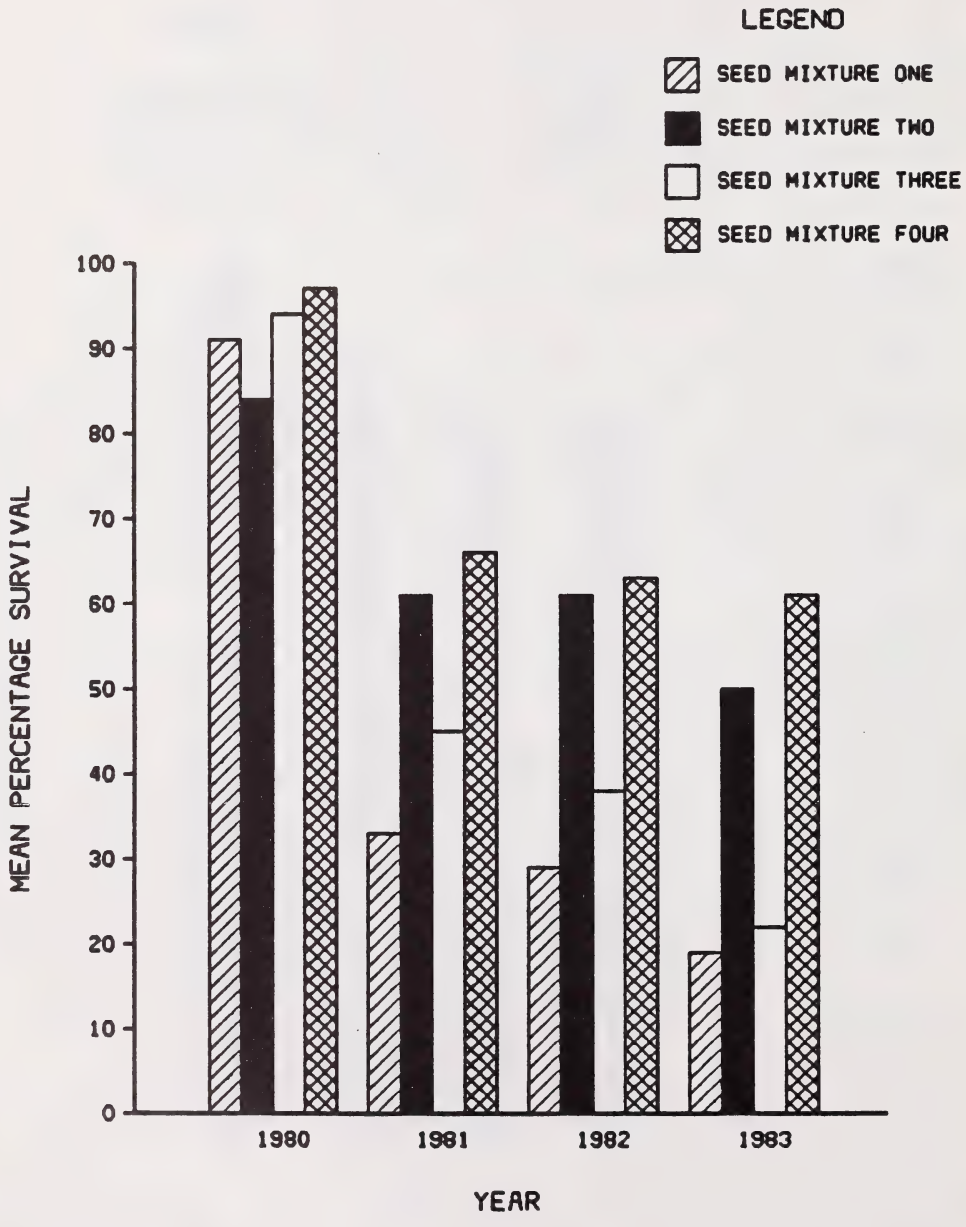


Figure 8

Total Mean Percentage Survival of White Spruce by Seed Mixture Treatment

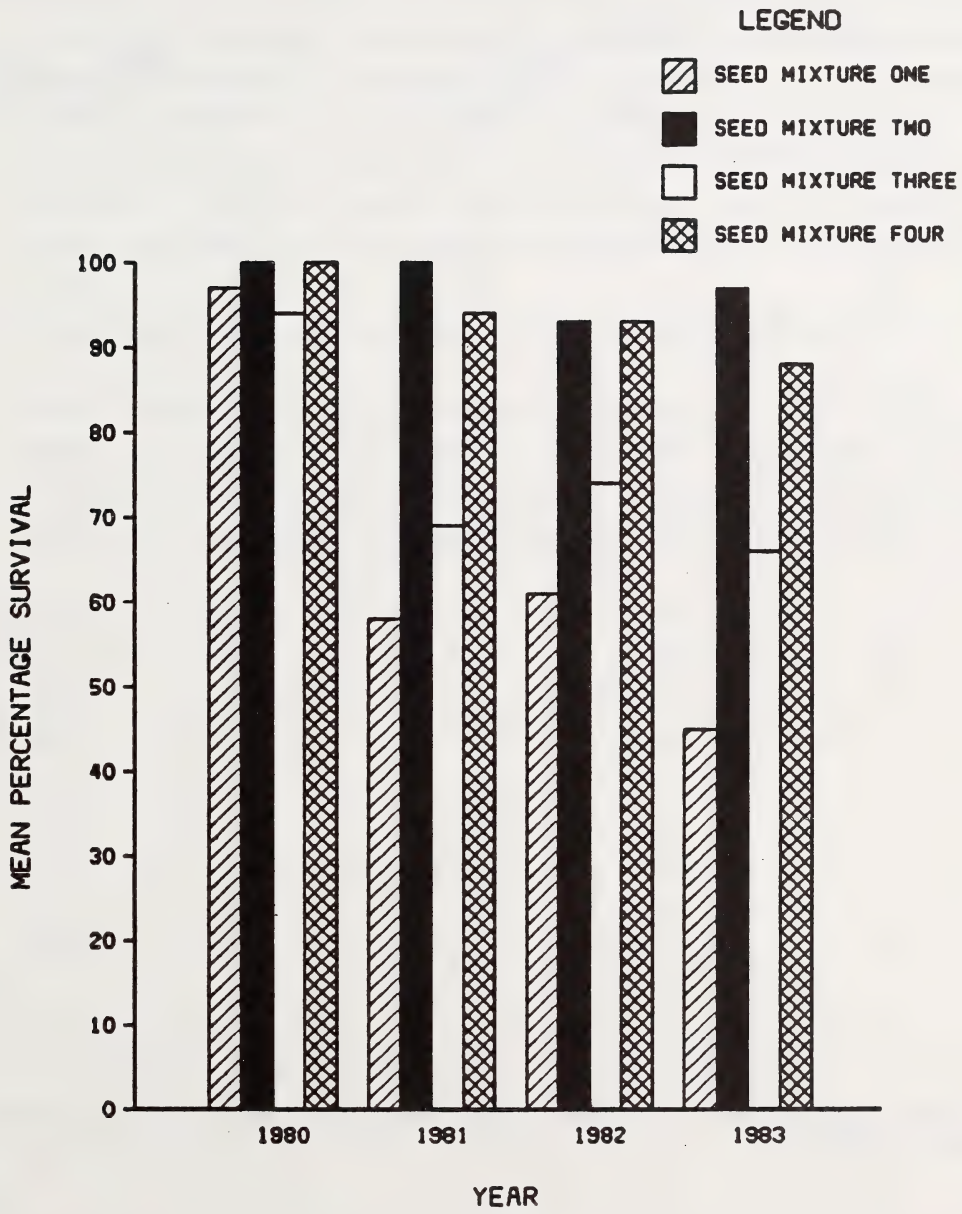


Table 7

Lodgepole Pine and White Spruce Growth in Relation to Seed Mixture

Year	Seed Mixture	Growth *			
		Pine		Spruce	
		Total Height	Incremental Height	Total Height	Incremental Height
1979	1	6.6	2.2	9.6	2.5
	2	7.3	1.6	8.9	1.5
	3	7.3	1.5	10.5	3.0
	4	6.6	1.8	9.4	1.8
1980	1	9.9	3.9	13.2	2.7
	2	11.7	4.7	14.4	5.4
	3	11.3	3.6	12.8	3.1
	4	11.1	4.0	15.1	4.9
1981	1	13.2	4.9	15.4	2.5
	2	18.5	6.6	17.4	3.4
	3	14.3	1.7	13.1	1.9
	4	15.1	5.3	19.6	4.8
1983	1	43.6	14.4	28.5	8.0
	2	46.1	13.9	30.1	6.5
	3	25.4	10.1	25.0	5.9
	4	37.5	12.4	35.3	8.5

* Growth expressed as either mean total height in cm or mean incremental height in cm.

Reforestation on Sites Cleared but Otherwise Undisturbed

A listing of the number of surviving tree seedlings on the "undisturbed" plots is given in Table 8. Seedling survival was very good on the upslope plots and reduced on the moist downslope plots. In general tree seedling growth was better, particularily in the upslope plots, on the "undisturbed" study other on the "disturbed" reforestation plots, (Table 9). The improved growth and survival of outplanted seedlings on undisturbed plots is probably due to the lack of a competitive herbaceous cover surrounding the trees (Table 10).

Small Mammal Population Dynamics and Reforestation Success

Small mammals were found to be implicated in up to 1/3 of the tree seedling mortality observed on the test mine (Figure 9). Preliminary data analysis of the food habits, habitat requirements and populations indicate that the meadow vole may be responsible for the majority of the small mammal caused mortality.

Table 8

Survival of Outplanted Lodgepole Pine on "Undisturbed Plots"

Year	Treatment		Survival*			
			Lodgepole Pine		White Spruce	
			Trees	%	Trees	%
1980	upslope	13	13	92.8	14	100
	downslope	13	13	100	13	100
1981	upslope	13	13	92.8	13	92.8
	downslope	12	12	92.3		84.6
1982	upslope	13	13	92.8	12	85.7
	downslope	12	12	92.3	7	53.8
1983	upslope	13	13	92.8	12	85.7
	downslope	10	10	76.9	7	53.8

* based on 14 outplanted trees on upslope treatment and 13 outplanted trees on downslope treatment.

Table 9

Total Height and Height Increments for Lodgepole Pine and White Spruce on "Undisturbed" Plots

Year	Treatment	Growth *			
		Pine		Spruce	
		Total Height	Incremental Height	Total Height	Incremental Height
1979	upslope	7.6	2.1	7.6	1.3
	downslope	5.9	1.7	5.8	1.5
1980	upslope	14.5	6.7	12.1	6.0
	downslope	11.4	5.0	8.9	3.4
1981	upslope	26.9	12.4	21.9	8.3
	downslope	11.4	5.0	8.9	3.4
1983	upslope	64.8	23.7	49.6	16.1
	downslope	34.8	13.9	21.4	6.1

* Growth expressed as mean total height (cm) and mean incremental height (cm) for 3 plots per treatment.

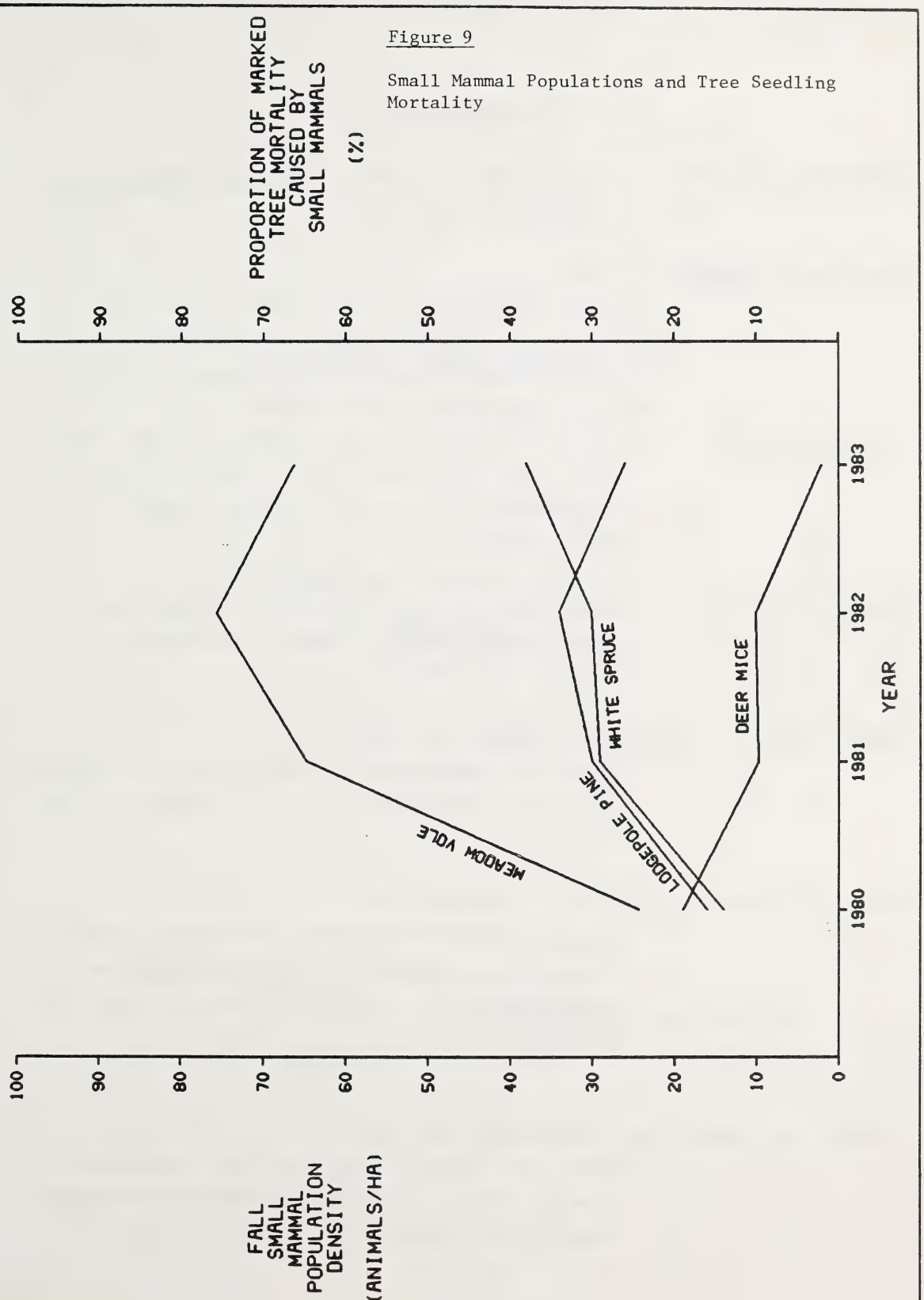
Table 10

Herbaceous Cover Recorded for "Undisturbed" plots

Year	Treatment	Total Living Cover (%)	Vegetative Species
1979	upslope	02	blueberry, dogwood,
	downslope	04	bunchberry, laborador tea, coltsfoot, fireweed raspberry, sedges
1980	upslope	10	reedgrass, bluegrass,
	downslope	15	hairgrass, sedges, aster, strawberry, yarrow, horesetail, laborador tea, bunch-berry, buffalo berry, blueberry, cranberry, balson poplar
1981	upslope	50	reedgrass, rye grass,
	downslope	20	fireweed, raspberry, strawberry, rose, bunchberry, buffalo-berry, willow, aspen

Figure 9

Small Mammal Populations and Tree Seedling Mortality



REFERENCE CITED

BARBEHENN, K.R. 1955. A field study of growth in Microtis pennsylvanicus J. Mammalogy 36:533-344.

ESSO MINERALS CANADA LTD. 1979. Final Reclamation Plan: Judy Creek Test Pit Unpublished Report Submitted to Environment Alberta, Land Conservation and Reclamation Council. 85 pp

FULLER, W.A. 1969. Changes in numbers of three species of small rodents near Great Slave Lake, N.W.T. 1964-1967 and their significance for general population theory. Ann. Zool. 6:34-55.

FULLER, W.A. 1977. Demography of a subarctic population of Clethrionomys gapperi: numbers and survival. Can. J. Zool. 55: 42-51.

MORRISON, DR., F.A. RYSER, and STRECKER, R.L. 1954. Growth and development of temperature regulation in the tundra red-backed vole. J. Mammalogy. 35: 376-386.

KREBS, C.J., KELLER, B.L., and R.H. TAMARIN. 1969. Microtis population biology: demographic changes in fluctuating populations of M. ochrogaster and M. pennsylvanicus in southern Indiana. Ecology 50: 587-607.

WATSON, L.E., PARKER, R.W. and POLSTER, D.F. 1980. Manual of species suitability for reclamation in Alberta. Alberta Land Conservation and Reclamation Council Report #RRTAC 80-5. 2 vols. 541 pp.

METHODOLGY AND INITIAL RESULTS OF THE BRYAN MOUNTAIN RECLAMATION TEST PLOTS

CROWS NEST RESOURCES LIMITED

APRIL 1984

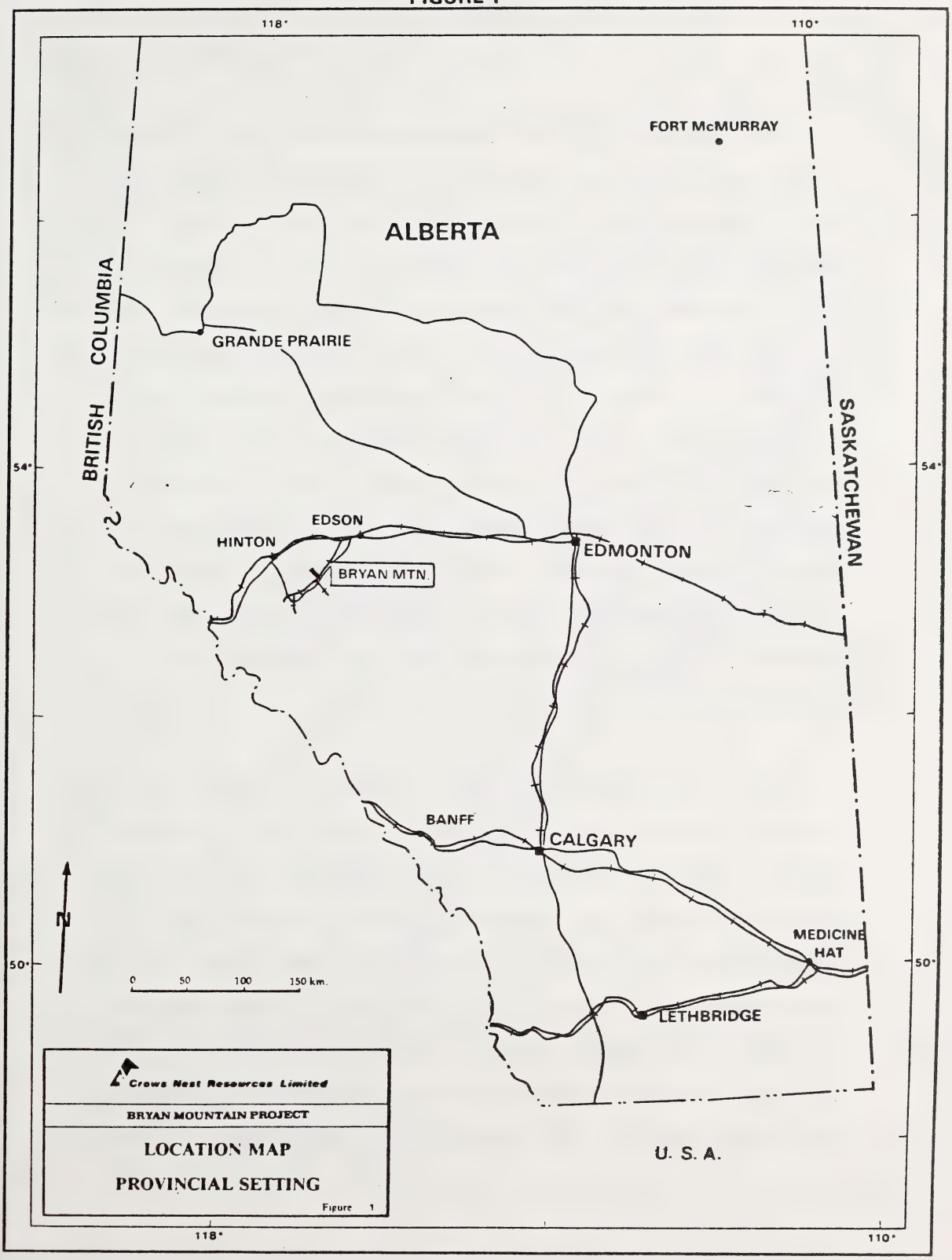
PREPARED BY: DEAN KITTLESON

The Bryan Mountain coal property is located 50 kilometers southeast of Hinton in the Alberta Foothills region (Fig.1). To establish a sound environmental data base the following studies were integrated into the proposed Bryan Mountain development plan:

- biophysical overview;
- soil survey, overburden characterization and interpretations for reclamation;
- construction of reclamation test plots.

The first study did not relate directly to the reclamation activities on Bryan Mountain but did provide preliminary assessment on land use capabilities and any potential development impacts. Using the results of this study, CNRL determined post-mining land use would most likely be commercial forestry and some wildlife habitat. To complete the data base from which an effective reclamation plan could be developed CNRL carried out the latter two studies.

FIGURE 1


118°
110°
FORT McMURRAY
ALBERTA
BRITISH COLUMBIA
SASKATCHEWAN
GRANDE PRAIRIE
54°
EDSON
HINTON
EDMONTON
BRYAN MTN.
BANFF
CALGARY
MEDICINE HAT
LETHBRIDGE
50°
N
0 50 100 150 km.
U. S. A.
Crows Nest Resources Limited
BRYAN MOUNTAIN PROJECT
LOCATION MAP
PROVINCIAL SETTING
Figure 1

The objective of the soil survey and overburden characterization was to identify existing soils and overburden; once identified, the results could be used to evaluate the reclamation capabilities of the materials. The study identified organic surface soils (comprised of slash, muskeg and peat bogs) and overburden (comprised of till material) as the dominant components (Fig. 2). CNRL determined through laboratory analysis that these materials, used individually, would be of poor suitability for successful reclamation. However, because of the variations in physical and chemical properties and the available quantities of each, several favourable soil profile reconstruction options could be considered. CNRL therefore proposed a reclamation test plot study to examine the available options and, assuming commercial forestry as the dominant post-mining land use, the success of reforestation.

The test plots were constructed in conjunction with the excavation and bulk sampling of two coal test pits in early 1982. The project design was similar for the two 30 m x 35 m plots and the undisturbed reference plots (Fig. 3). The first step involved the stripping and stockpiling of the first 15 cm of topsoil or organic layer. The subsoil units, comprised of "coaly till" or "non-coaly till" were then stripped to a depth of two meters, segregated and stockpiled separately. Finally the remainder of the overburden material and bedrock were stripped and mass spoiled together. After sampling the coal, the mass spoil material

FIGURE 2

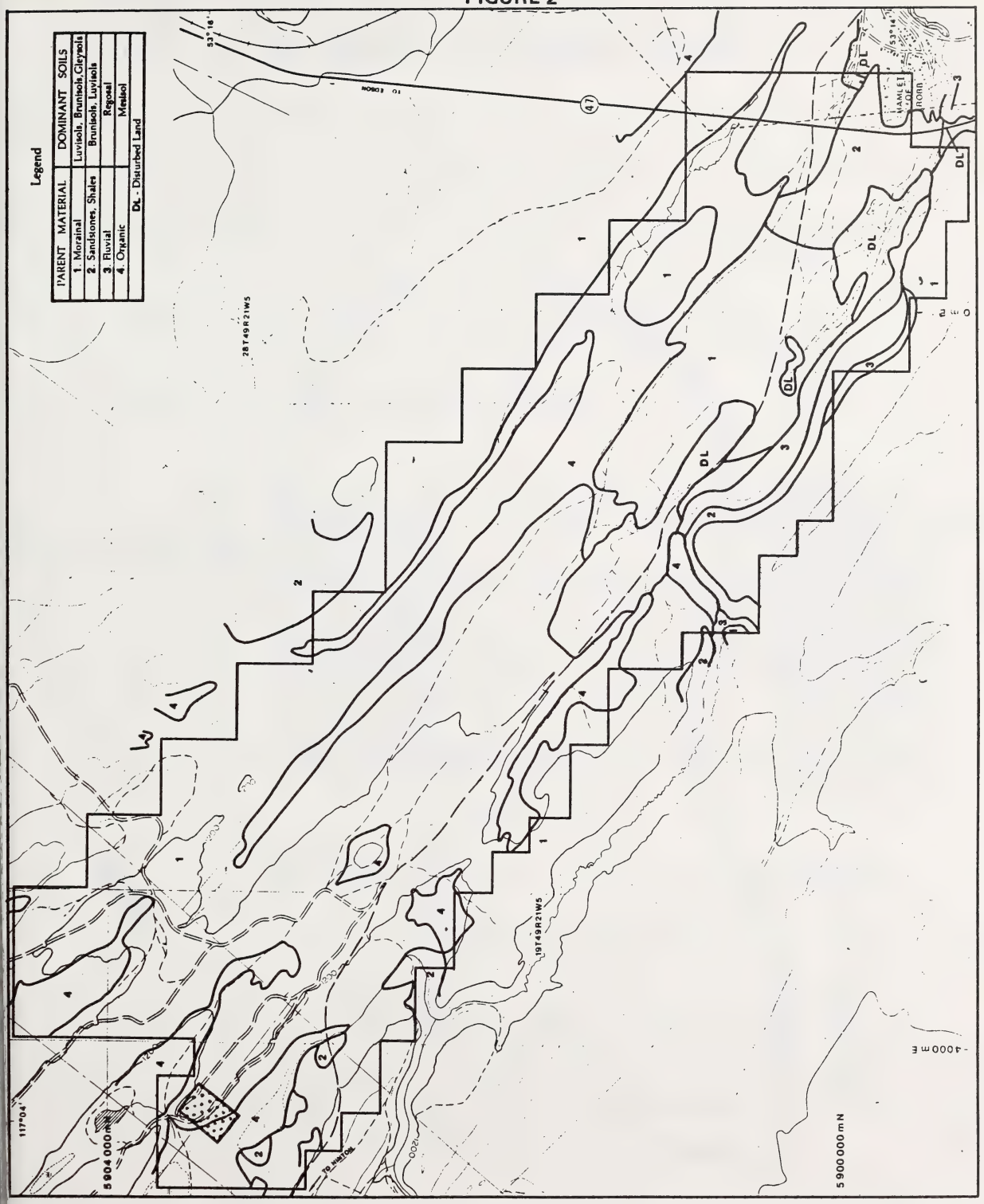
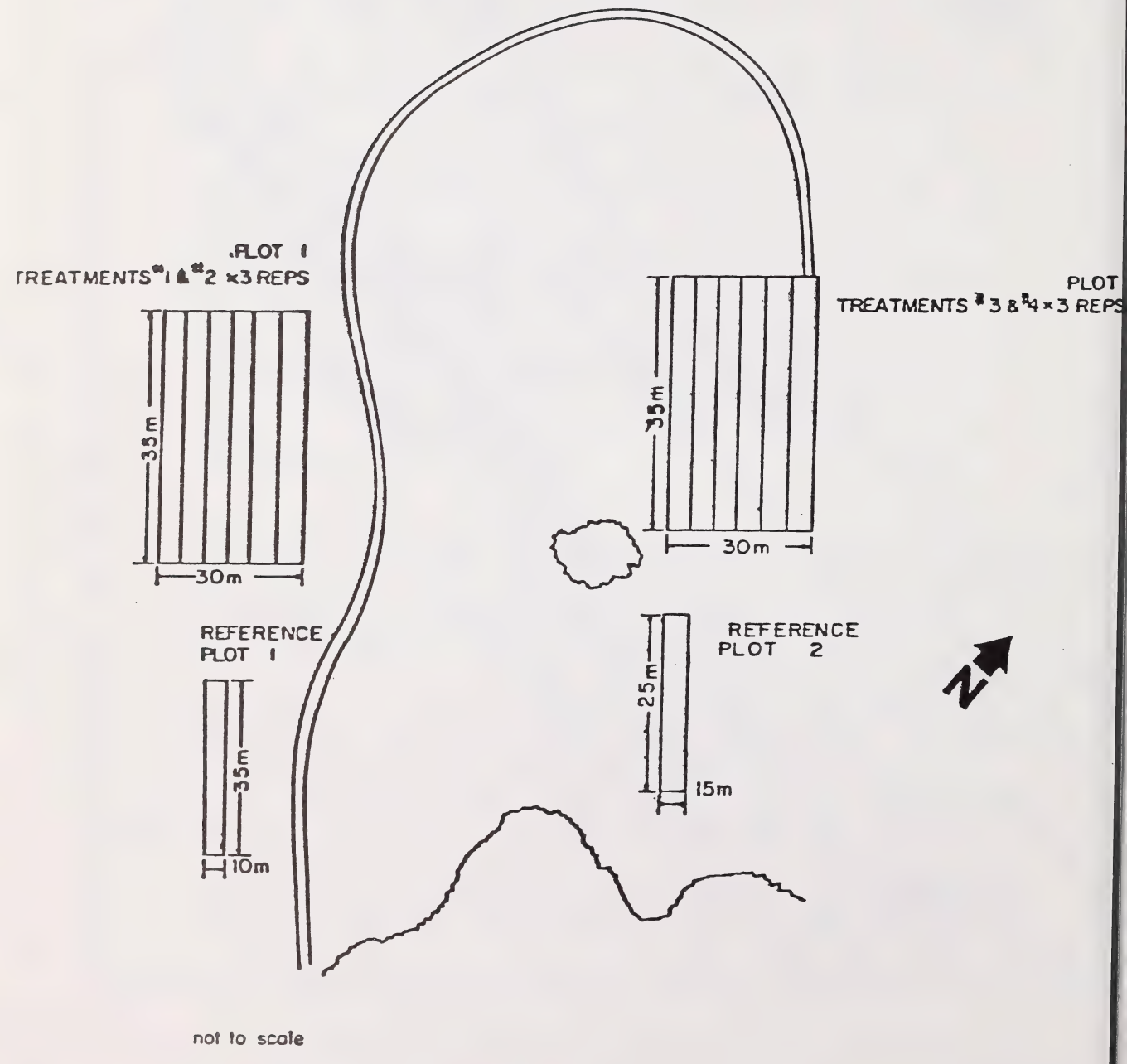

Legend
PARENT MATERIAL
DOMINANT SOILS
1. Morainal
Luvisols, Brunisols, Gleysols
2. Sandstones, Shales
Brunisols, Luvisols
3. Fluvial
Regosol
4. Organic
Mesisol
DL - Disturbed Land
28T49R21W5
19T49R21W5
HAMLET OF ROSS
TO EDSON
TO ALBERTA
5 904 000 mN
5 900 000 mN
400000 E
117°04'
53°16'
53°14'
DL
1
2
3
4

FIGURE 3 Plan View of Construction Layout
Bryan Mountain Reclamation Plots



not to scale

was returned to the pit, levelled and compacted. The subsoil units were then replaced in six 5 m x 35 m subplots, one metre thick alternating between a "coaly till" unit, and a "non-coaly till" unit thereby establishing three replicates for each soil profile option used (Fig. 4). The final step was spreading the salvaged topsoil evenly across each plot until all subplots were covered.

After replacing the topsoil in June, 1982, the test plots were planted with two commercial timber species, lodgepole pine and white spruce. Each subplot consisted of three rows of alternating species at one metre spacing, totalling 25 seedlings per row (Figs. 5 & 6). A total of 900 seedlings were planted on the reconstructed soils treatments. Approximately 100 additional seedlings were planted in the two reference plots, each located in proximity to the test plots (Figs. 7 & 8).

Monitoring of the test plots did and/or will involve periodic soil sampling and water table observations for each replicate and reference plot. Annual growth and survival rates will be measured twice a year and results will be modelled statistically to compare each of the subplots within each plot. An initial assessment of the subplots was carried out in October, 1982. Initial height measurements were taken and recorded as was an initial survivorship assessment.

FIGURE 4

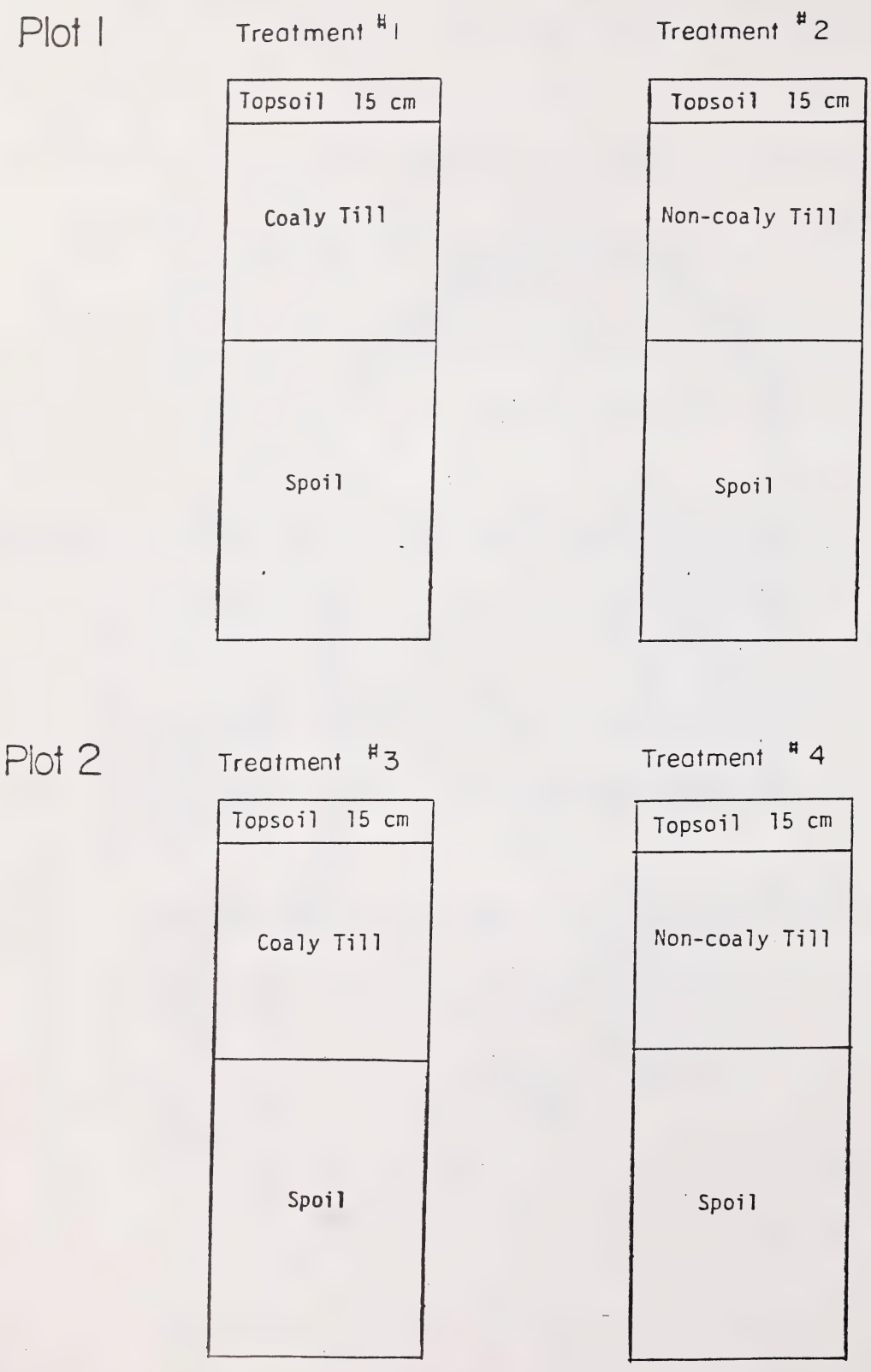

Plot 1
Treatment #1
Topsoil 15 cm
Coaly Till
Spoil
Treatment #2
Topsoil 15 cm
Non-coaly Till
Spoil
Plot 2
Treatment #3
Topsoil 15 cm
Coaly Till
Spoil
Treatment #4
Topsoil 15 cm
Non-coaly Till
Spoil

FIGURE 5 Design of Plot I

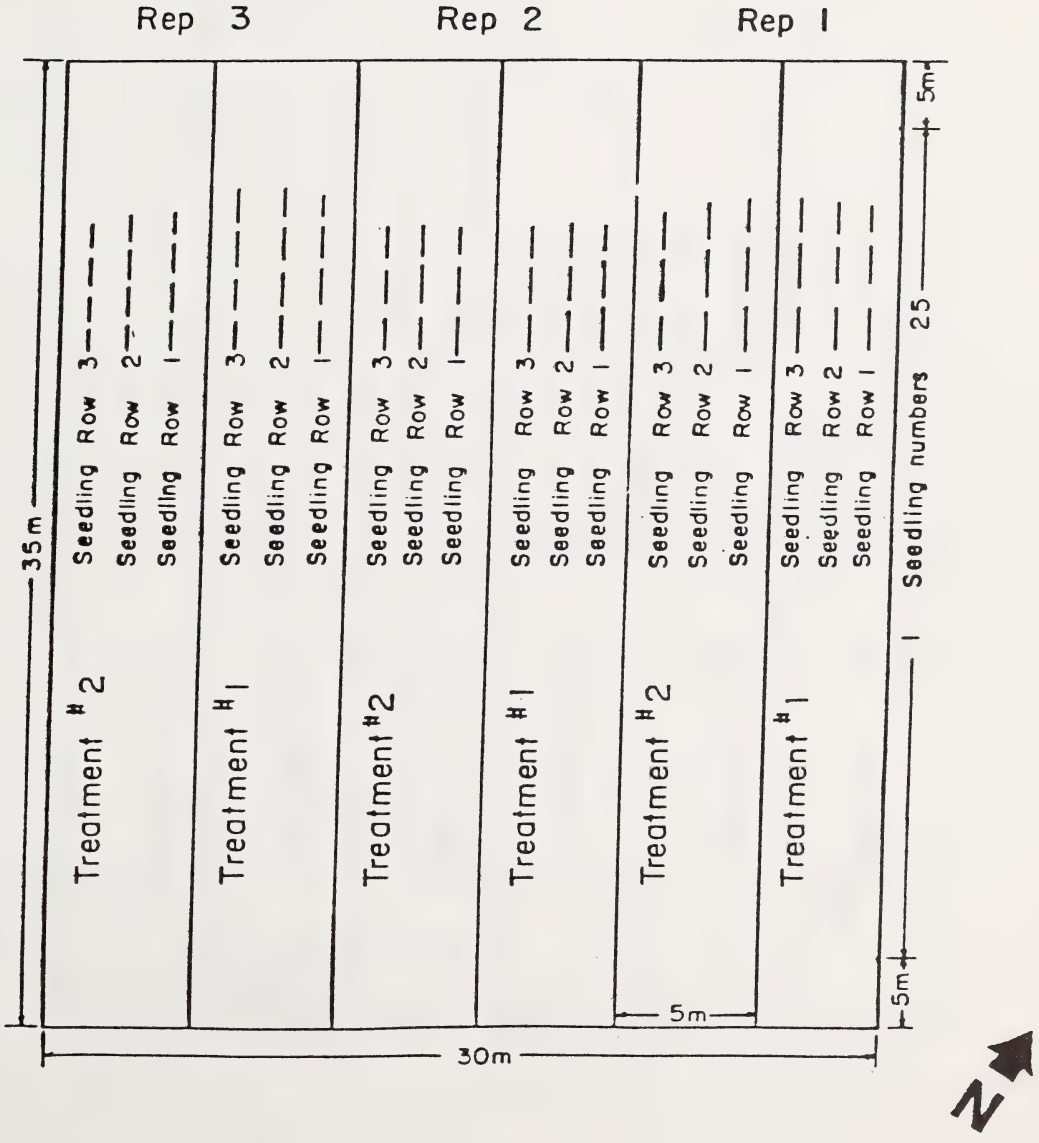


FIGURE 6 Design of Plot 2

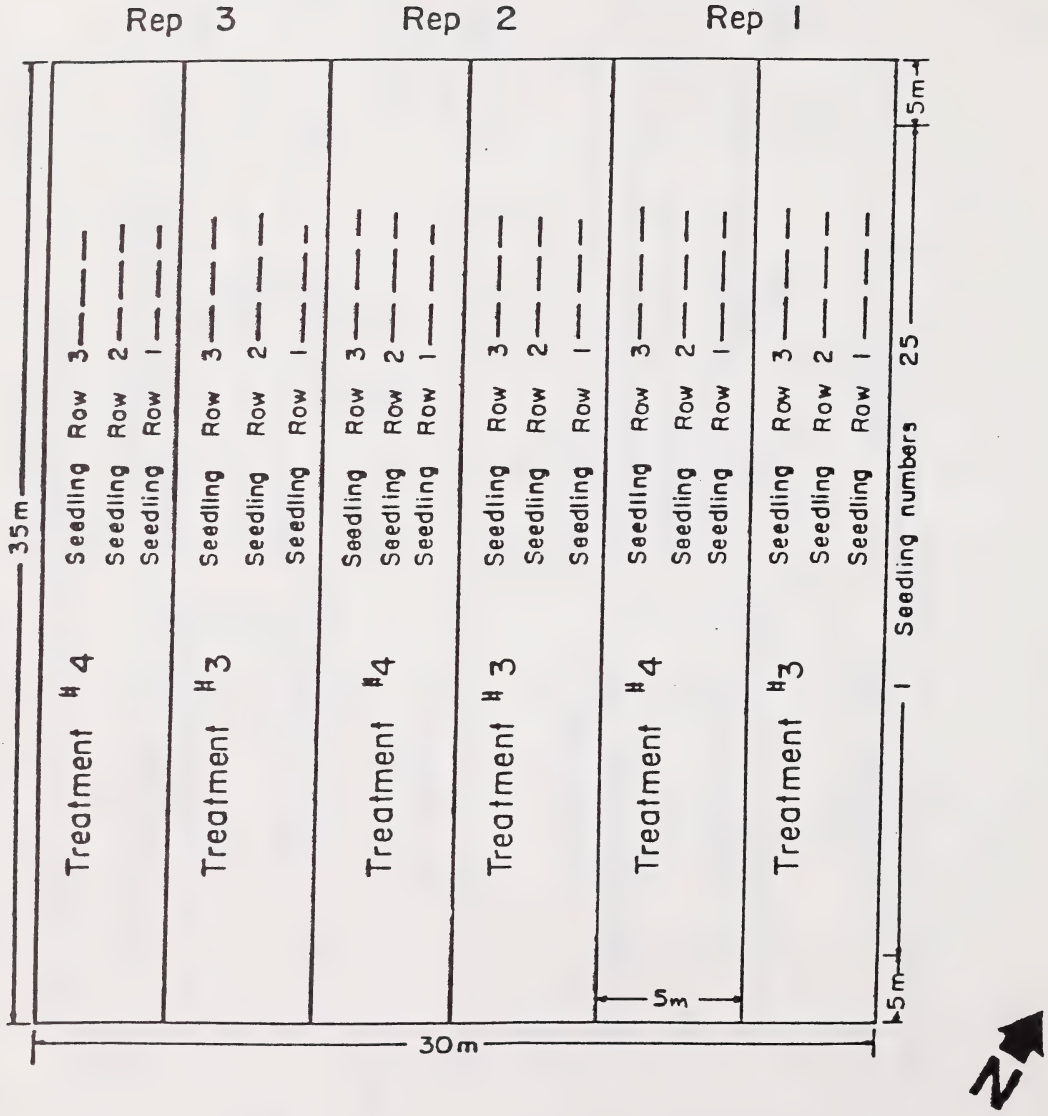


FIGURE 7 Reference : Plot I

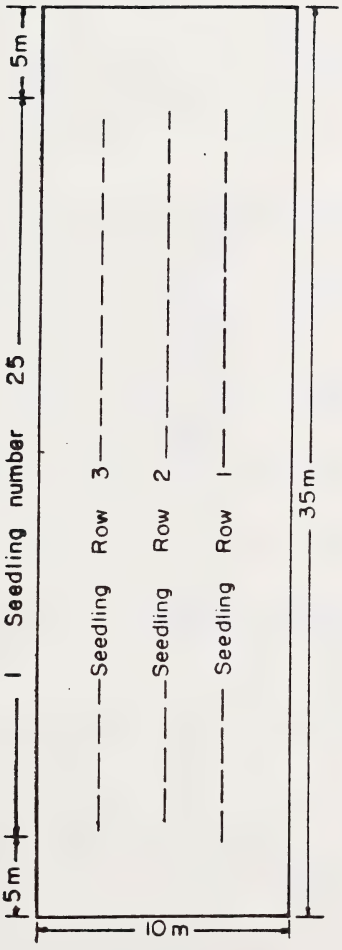
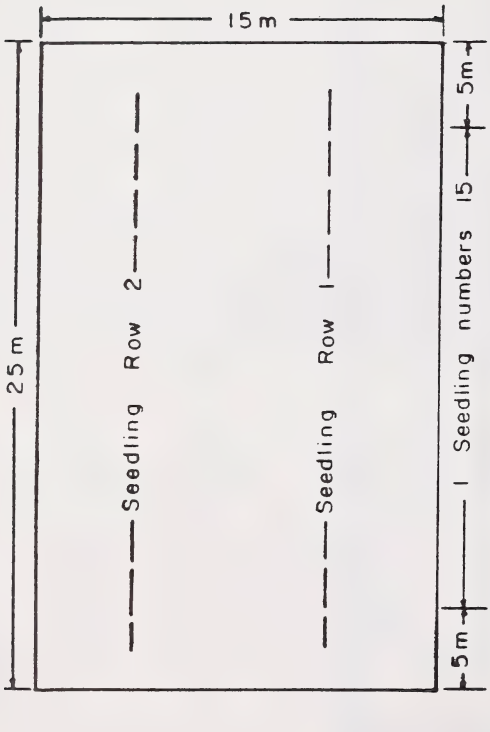


FIGURE 8 Reference: Plot 2



The results showed no mortality and it appeared that the use of organic slash and debris was protecting the seedlings from wind and sun exposure. The initial statistical results for the first full year's monitoring are based upon the following assessments: snow cover in March, 1983, survivorship and vigor ratings in May, 1983 and finally, seedling growth in September, 1983.

The snow cover assessment indicated snow accumulation of 40 cm with a consistent snow pack covering all seedlings in both test plots. The adjacent reference plots had a less evenly distributed snow pack, probably because of the established native species. It is too early to determine the long term effects of snow pack on successful seedling establishment.

Survivorship was assessed with positive results ranging from a low of 84 percent up to highs of 100 percent depending upon soil treatments and species. Seedling vigor was also rated using categories poor, fair, good and excellent (Table 1). The rating was based upon colour, presence of needles, presence of terminal buds and stem dessication. There was no insect or rodent damage visible, limited competition from native species and it was confirmed that the use of organic slash and debris provided effective protection from wind and sun exposure. Soil moisture was evaluated by simple manual texturing and appeared adequate with no prominent ponding or erosional runs.

TABLE 1

Area	% Survivorship (by Vigor Class)					% Mortality
	Excellent	Good	Fair	Poor	Total	
Reference Plot 1						
White Spruce	68.4	26.3	5.3	0.0	100.0	0.0
Lodgepole Pine	65.7	22.9	8.5	0.0	97.1	2.9
Plot 1 Treatment 1						
White Spruce	28.6	34.3	28.6	5.7	97.2	2.8
Lodgepole Pine	28.9	51.6	14.3	5.2	100.0	0.0
Plot 1 Treatment 2						
White Spruce	22.2	38.8	27.8	5.5	94.3	5.7
Lodgepole Pine	26.9	53.8	19.3	0.0	100.0	0.0
Reference Plot 2						
White Spruce	75.3	24.7	0.0	0.0	100.0	0.0
Lodgepole Pine	68.5	31.5	0.0	0.0	100.0	0.0
Plot 2 Treatment 3						
White Spruce	37.5	35.0	12.5	15.0	100.0	0.0
Lodgepole Pine	7.6	19.2	23.0	34.6	84.3	15.7
Plot 2 Treatment 4						
White Spruce	48.4	29.0	6.4	6.4	90.2	9.8
Lodgepole Pine	17.1	28.6	25.7	17.1	88.5	11.5

In September, 1983 the seedling growth assessment involved actual new growth measurements rather than the calculated increases based upon the 1982/83 height measurements. Discrepancies became apparent between actual new growth figures and the calculated height increases and were attributed to the following factors, soil settling, frost heaving and loss of apical dominance. As these factors are significant in the first few annual evaluations, actual new growth measurements provided a more valid and useful statistical analysis. Based upon this analysis, productivity differences between treatments were determined and these results plus the new growth measurements are summarized in Tables 2,3,4 and 5.

In conclusion, the initial year's results for the Bryan Mountain test plots provide valuable information regarding materials handling, topsoil/subsoil salvage as well as seedling survival and vigor ratings. It is, however, too early in the project to develop any trends regarding the success or failure of soil profile treatments, the effect of snow pack on seedlings in disturbed soils and the effect of competition from re-established native vegetation.

Table 2 Summary of Statistical Analysis Results*
Plot 1

Species	Treatment 1 (coaly till)	Treatment 2 (non-coaly till)	Reference Site
Pine	A	A	A
Spruce	B	b**	B

* Notation

A, B = no significant difference in productivity
a, b = significant difference in productivity

** lower productivity

Table 3 Summary of Statistical Analysis Results*
Plot 2

Species	Treatment 3 (coaly till)	Treatment 4 (non-coaly till)	Reference Site
Pine	A	A	a***
Spruce	b**	B	B

* Notation

A, B = no significant difference in productivity
a, b = significant difference in productivity

** lower productivity

*** higher productivity

Table 4 Summary of New Growth Measurements in Plot 1

Species	Treatment 1 (coaly till)	Treatment 2 (non-coaly till)	Reference Site
Pine	2 cm to 10 cm	1.5 cm to 12 cm	3 cm to 9 cm
Spruce	.5 cm to 13.5 cm	.5 cm to 8 cm	1 cm to 6 cm

Table 5 Summary of New Growth Measurements in Plot 2

Species	Treatment 3 (coaly till)	Treatment 4 (non-coaly till)	Reference Site
Pine	1.5 cm to 13 cm	2 cm to 14 cm	3 cm to 14 cm
Spruce	.5 cm to 17 cm	1 cm to 17 cm	3 cm to 19 cm

WOODY PLANT DEMONSTRATIONS AND TRIALS ON LAND DISTURBANCE IN THE EASTERN SLOPES

P. King
Reforestation and Reclamation Branch
Alberta Forest Service

1. INTRODUCTION

In the Rocky Mountain Eastern Slopes of Alberta, the forests are a significant renewable resource, representing a substantial portion and use of the land base and contribution to the economy. Therefore, when carrying out reclamation on large-scale industrial disturbances, the replacement of the pre-disturbance forest resource is frequently one of the primary objectives. Afforestation practice on such disturbances, particularly on severely altered areas such as coal mines, may differ from that used in traditional reforestation.

To date, relatively little experience has been obtained in establishing woody plant species on reclamation sites in the region. This paper presents the results of three relevant investigations. The first deals with demonstrations of exotic trees and shrubs which were established on mined areas in southwestern Alberta. The second involves two trials examining the competitive effects of erosion-controlling grass and legume mixtures on interplanted coniferous trees. Finally, the results of two demonstrations of coniferous species on unamended coal mine spoil are presented.

2. EXOTIC TREE AND SHRUB DEMONSTRATIONS

2.1 Methods

Twelve exotic tree and shrub species were variously planted at six localities in the southern Eastern Slopes during 1977. The woody plants included buffaloberry, caragana, American elm, Siberian elm, green ash, Manitoba maple, balsam poplar, Northwest poplar, Vernirubens poplar, Walker poplar, Russian olive and basford willow. All planting stock was bareroot, originating from the Indian Head Nursery, Saskatchewan. Table 1 presents a summary of the site and planting information for the demonstrations. It should be noted that all plantings were established on non-topsoiled spoil materials.

Assessments on the trees were carried out in 1978, at the end of the second growing season after establishment. At that time, only survival was assessed.

2.2 Results and Discussion

The second season survival data for the trees and shrubs are given in Table 2. Mean survival across sites ranged from 52 percent for buffaloberry to zero percent for Vernirubens poplar. Survival within species was also variable.

Since the demonstrations were established on sites with a variety of spoils, varying elevations and differing cover crops, interpretation of the data is difficult. However, several inferences may be drawn from the

Table 1

SITE AND PLANTING INFORMATION FOR

EXOTIC TREE AND SHRUB DEMONSTRATIONS

Site	Location	Elevation (m)	Exotic Tree and Shrub Species Established	Seeded Cover Crop
Tent Mountain	SE 23-7-6-W5	1 859	green ash, Manitoba maple, balsam poplar, Northwest poplar, Russian olive, basford willow	sweet clover, wheat and oats
Coleman	N½ 6-8-4-W5	1 341	buffaloberry, caragana, Siberian elm, green ash	sweet clover
Nez Perce (Lower Slope)	E½ 29-8-4-W5	1 753	American elm, green ash, Manitoba maple, balsam poplar, Walker poplar	alfalfa
Nez Perce (Upper Slope)	E½ 29-8-4-W5	1 753	caragana, American elm, Siberian elm, Northwest poplar, Walker poplar	creeping red fescue, timothy, Kentucky bluegrass, bromegrass, white clover and sweet clover (interseeded after one year)
Racehorse Creek	7-10-4-W5	1 981	caragana, Vernirubens poplar, basford willow	creeping red fescue, timothy, Kentucky bluegrass, bromegrass and sweet clover

Table 2

SURVIVAL IN EXOTIC WOODY PLANT DEMONSTRATIONS

AFTER TWO GROWING SEASONS

SPECIES	NUMBER OF SITES	SURVIVAL BY SITE (%)					MEAN SURVIVAL (%)
		Tent Mountain (el. 1 859 m)	Coleman (el. 1 341 m)	Nez Perce - Lower Slope (el. 1 753 m)	Nez Perce - Upper Slope (el. 1 753 m)	Racehorse Creek (el. 1 981 m)	
Buffaloberry	1		52				52
Northwest poplar	2	66			16		41
Caragana	3		56		41	24	40
Siberian elm	2		42		38		40
American elm	2			31	48		39
Green ash	3	14	62	26			34
Basford willow	2	4				50	27
Russian olive	2	0	46				23
Balsam poplar	2	27		15			21
Walker poplar	2			0	10		5
Manitoba maple	2	5		3			4
Vernirubens poplar	1			0			0

demonstrations. First, some of the exotic species, such as buffaloberry, Northwest poplar, caragana and Siberian elm, generally demonstrated higher survival and may be candidates for operational plantings. Second, the sites are considered to be relatively harsh and the survival performance may not be indicative of non-adaptability. Site amelioration practices, such as topsoiling, may have improved site attributes and yielded greater survival. Third, the use of non-native plant species must be questioned if wildland-oriented land uses are a primary objective in reclamation. In such situations, native trees and shrubs having adaptability and utility in attaining land-use goals would be preferable.

3. INFLUENCE OF GRASS AND LEGUME MIXTURES ON THE PERFORMANCE OF INTER-PLANTED CONIFEROUS TREES

3.1 Methods

Two experiments have been established. One is at latitude 49°31' N and longitude 114°31' W (Lynx Creek, southern foothills); the other is located at latitude 52°55' N and longitude 116°25' W (Fairfax Lake, central foothills). At each experimental site a 2 X 4 X 2 factorial experiment in randomized complete blocks was established. Treatments in each experiment included two seed mixtures, four seed mixture application rates and two tree species. Each experimental block was replicated three times.

The seed mixture treatments for each of the sites are given in Table 3. The seed mixture application rates on both sites were 0.0, 8.4,

Table 3

AGRONOMIC SPECIES SEED MIXTURES TESTED AT FAIRFAX LAKE AND LYNX CREEK

Trial	Mixture Designation	Species	% (by weight)
Fairfax Lake	I (Edson Mix)	creeping red fescue (Boreal)	40
		white clover	20
		timothy (Climax)	20
		crested wheatgrass	20
	II (Bow-Crow Mix)	creeping red fescue (Boreal)	40
		white clover	12
		timothy (Climax)	24
		Canada bluegrass	24
Lynx Creek	I (Bow-Crow Mix)	creeping red fescue (Boreal)	40
		white clover	12
		timothy (Climax)	24
		Canada bluegrass	24
	II (Blairmore Mix)	creeping red fescue (Boreal)	50
		alsike clover	10
		timothy (Climax)	20
		Canada bluegrass	20

16.8, and 28.0 kg/ha. The tree species used were lodgepole pine and white spruce grown from seed of local origin and outplanted as 2-0 bareroot stock at 1 m X 1 m spacing.

The Fairfax Lake experimental site was prepared in late May, 1979, then seeded and fertilized in early July of the same year. The seed mixes were hand-broadcast and then lightly raked into the soil. All legume seeds were inoculated with the appropriate Rhizobium species immediately before seeding. After seeding, fertilizer was broadcast to supply 61.1 kg/ha N, 17.1 kg/ha P and 16.8 kg/ha S, as determined by soil analyses. Trees were interplanted at Fairfax Lake in early June of 1980. The seed lots used were lodgepole pine DE 53-21-76 and white spruce DE 51-25-5-75. The trees were bare root stock and hand-planted using the "hole planting" technique.

Site preparation, seeding and fertilizing at Lynx Creek were carried out in late June to early August, 1979. The site preparation and seeding technique were the same as discussed previously for Fairfax Lake. The analyses-determined fertilizer application rates used were 67.2 kg/ha N and 27.9 kg/ha K. The tree seedlings were interplanted in late May, 1980. Lodgepole pine DB 6-4-5-76 and white spruce DB 7-5-5 seed lots were used. The same planting method as described for Fairfax Lake was employed.

The control (0.0 kg/ha seed application rate) plots in both experiments were mechanically weeded early in the 1981 and 1983 growing seasons to minimize the competitive effects of any volunteer vegetation. No other maintenance has been carried out in the trials.

Grass-legume performance assessments included annual estimation of live ground cover and aerial living biomass. Information on the methodology

is summarized in Table 4. Assessments of the trees included total height and total diameter, from which annual and cumulative tree increments were calculated, and survival. Table 5 summarizes tree assessments. Data was analysed and presented using analysis of variance and Duncan's multiple range test at the one percent confidence level.

3.2 Results and Discussion

The ground covers for 1983 at the Fairfax Lake site are illustrated in Figure 1. The amount of ground cover was substantially less on the weeded controls than on seeded plots. In the plots on which the seed mixtures had been applied, the response among application rates was somewhat variable but the rate of change in cover levelled as the application rate increased. Cover at Fairfax Lake was independent of the tree species treatments as well as the grass-legume mixtures. The latter may be attributed to the similarity of the mixtures' major species components.

At Lynx Creek, the 1983 ground cover (Figure 2), averaged for tree species and grass-legume mixture treatments, was greater in the seeded plots than in the unseeded application rate controls. The differences in the mixtures, averaged over tree species, are significant only in the controls, a likely reflection of the weeding. For the 8.4 kg/ha application rate, the cover was greater in the lodgepole pine plots seeded to Mix I than in those with Mix II. No difference was found in the corresponding white spruce treatments or in any of the other tree species or grass-legume mixture plots.

Table 4

GRASS-LEGUME PERFORMANCE ASSESSMENT METHODOLOGY AND SAMPLING

Parameter	Methodology	Sampling Intensity
Total ground cover	Ocular estimate of live plant cover made using a 0.5 m X 0.5 m quadrat with a grid of 100 subplots. Number of filled subplots were counted and the partially-filled were pooled and counted. Cover expressed as the percentage of filled subplots.	Average based on eight subsamples per plot.
Aerial biomass (dry matter production)	Over-dry weight of an aboveground clipping of all living plant materials. Clipping taken at a 1 cm height within a 0.5 m X 0.5 m quadrat.	Average based on eight subsamples per plot.

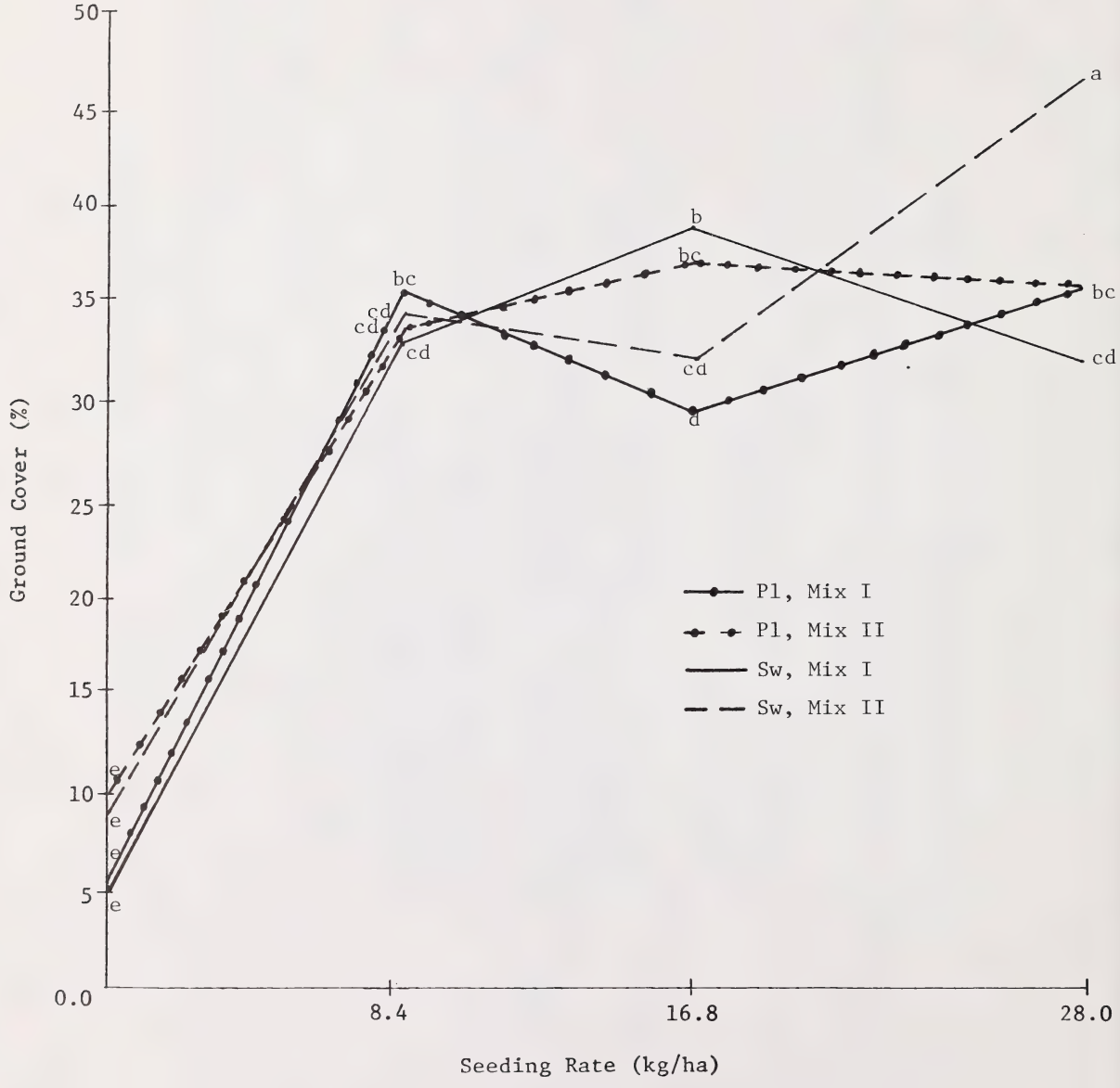
Table 5

TREE PERFORMANCE ASSESSMENT METHODOLOGY AND SAMPLING

Parameter	Methodology	Sampling Intensity
Total height	Measurement of the height of each sample tree from the root collar to the apex. Results to be reported as the annual height increment.	Ten permanent sample trees per plot.
Diameter	Measurement of the diameter of each sample tree (2.5 cm above the root collar). Results to be reported as the annual diameter increment.	Ten permanent sample trees per plot.
Survival	A count of the number of living sample trees. Results to be reported as a percentage.	Ten permanent sample trees per plot.

Figure 1

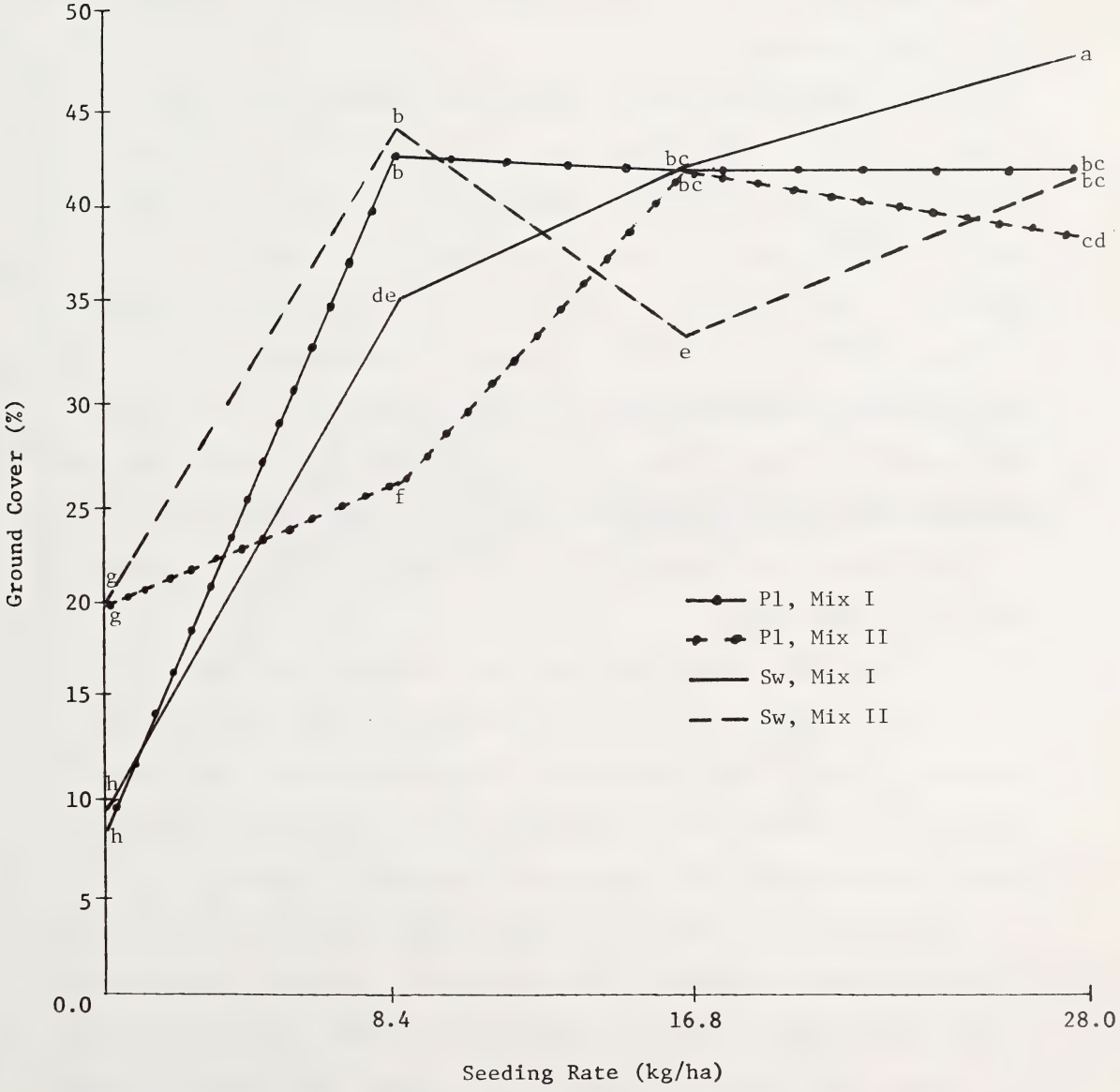
FAIRFAX LAKE GRASS AND LEGUME GROUND COVER (1983)



In all graphs, points labelled with the same letter are not significantly different at the 1 percent level, Duncan's Multiple Range Test.

Figure 2

LYNX CREEK GRASS AND LEGUME GROUND COVER (1983)



The grass-legume biomasses during 1983 at Fairfax Lake (Figure 3) followed much the same trends as ground cover. The data interpretation was also similar: biomass was much greater in seeded plots than on the controls while seed mixtures and tree species did not affect the amount of aerial biomass produced.

The above-ground biomass of grasses and legumes at Lynx Creek (Figure 4) was less in the controls than at the 8.4, 16.8 or 28.0 kg/ha application rates with mixture and tree species effects being non-significant. The differences in the grass-legume biomass, averaged over tree species, are significant only in the controls. As discussed under ground cover, the difference is probably a function of the weeding. At the 0.0 kg/ha rate, the grass-legume biomass in the lodgepole pine plots seeded to Mix I was less than in those with Mix II. In plots seeded at 8.4 kg/ha, pine plots had less biomass when seeded to Mix II than Mix I. For the spruce treatments at the 28.0 kg/ha rate, biomass was more with Mix I. No differences were found in the other plots.

In both experiments, grass and legume production was less in the controls than in the plots on which seed mixtures had been applied and the statistical effects of the mixtures and tree species were not significant. However, at the southern site, differences in the production of grasses and legumes did occur within some mixture and tree species treatments.

The survival of trees at both sites (Figure 5 and 6) was independent of all experimental treatments. The tree species, grass and legume mixtures and the rate at which the mixtures were applied did not affect tree mortality. However, this may not be interpreted as meaning that grasses and legumes

Figure 3

FAIRFAX LAKE GRASS AND LEGUME BIOMASS (1983)

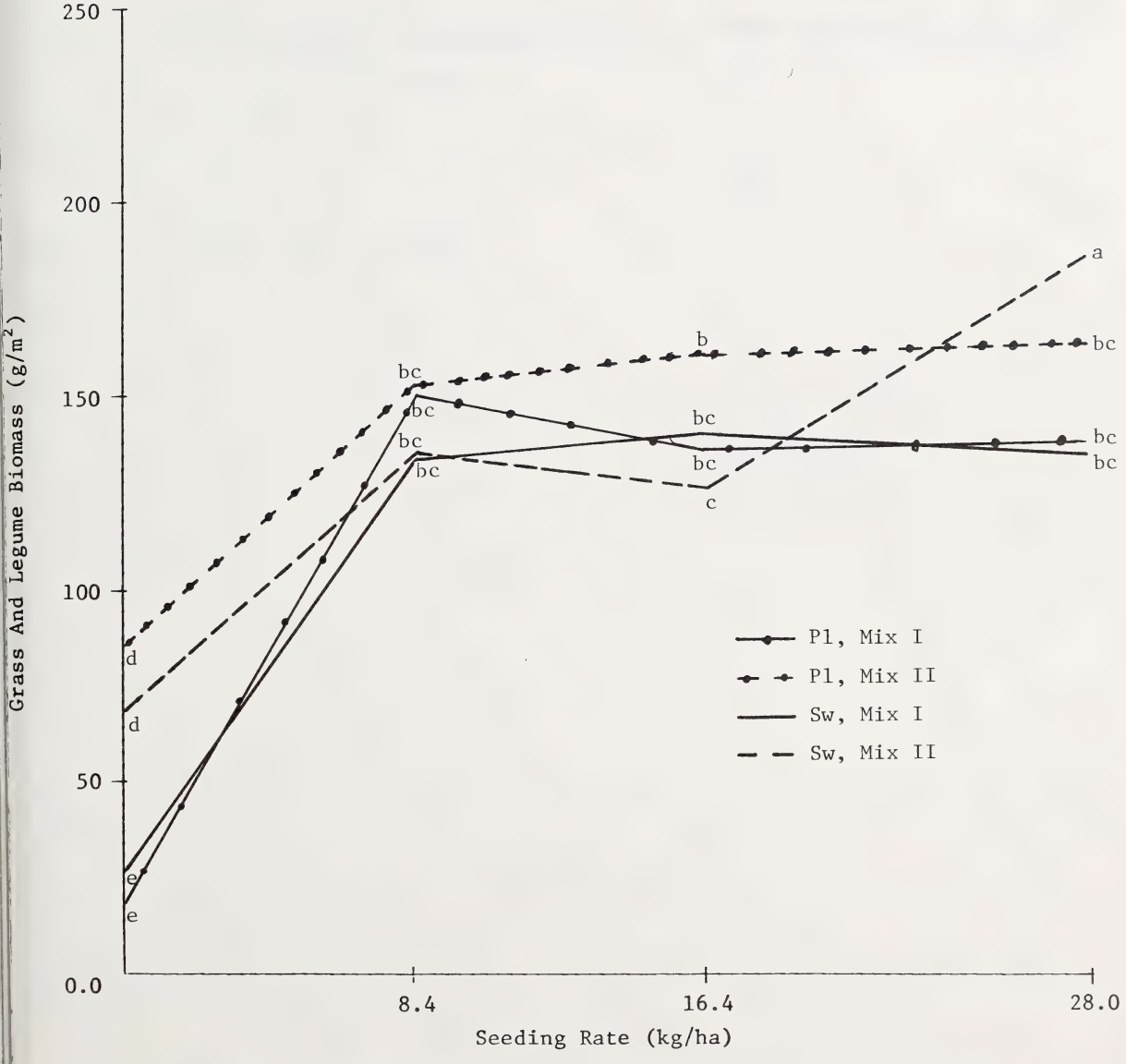


Figure 4

LYNX CREEK GRASS AND LEGUME BIOMASS (1983)

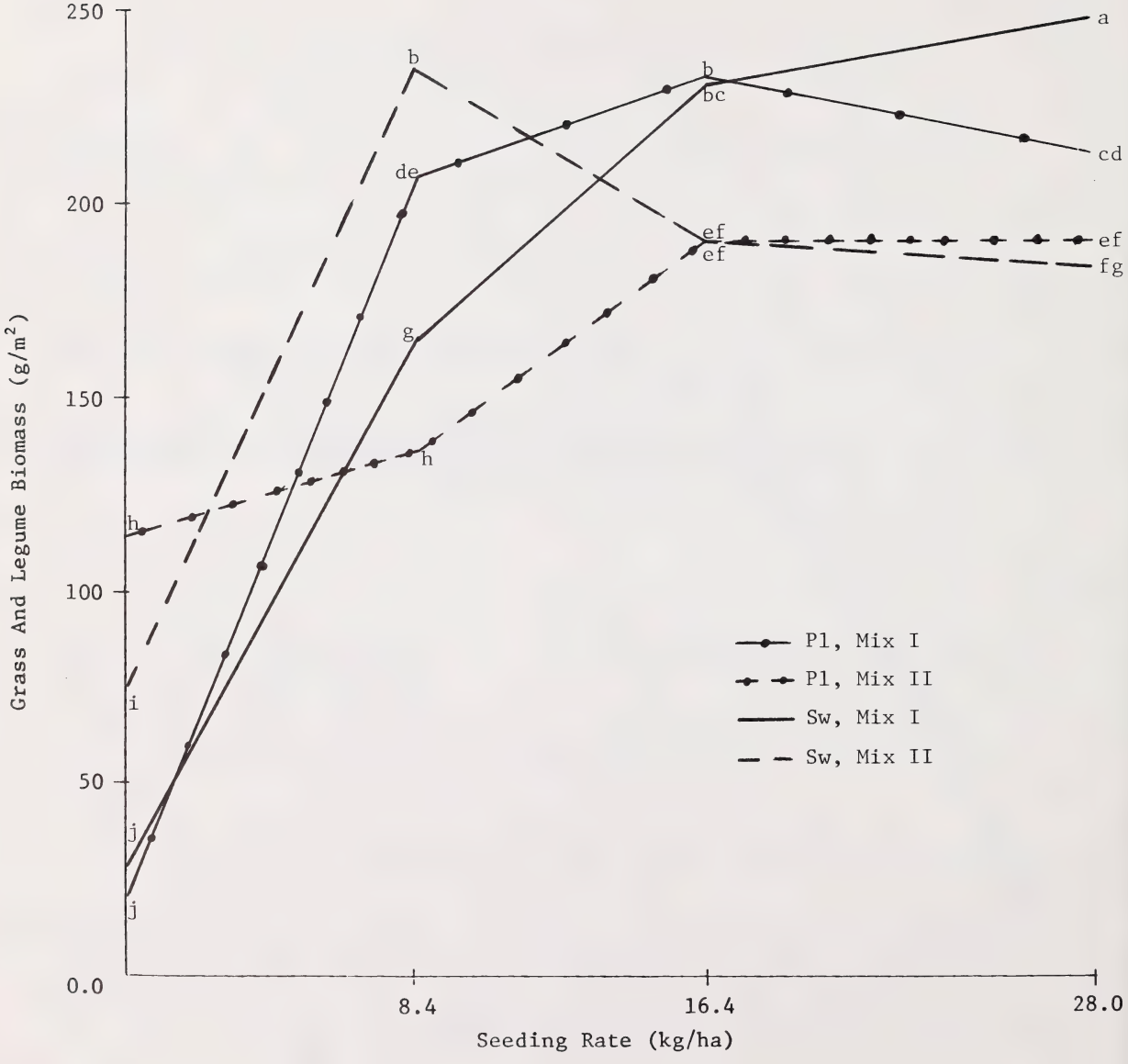


Figure 5

FAIRFAX LAKE TREE SURVIVAL (1983)

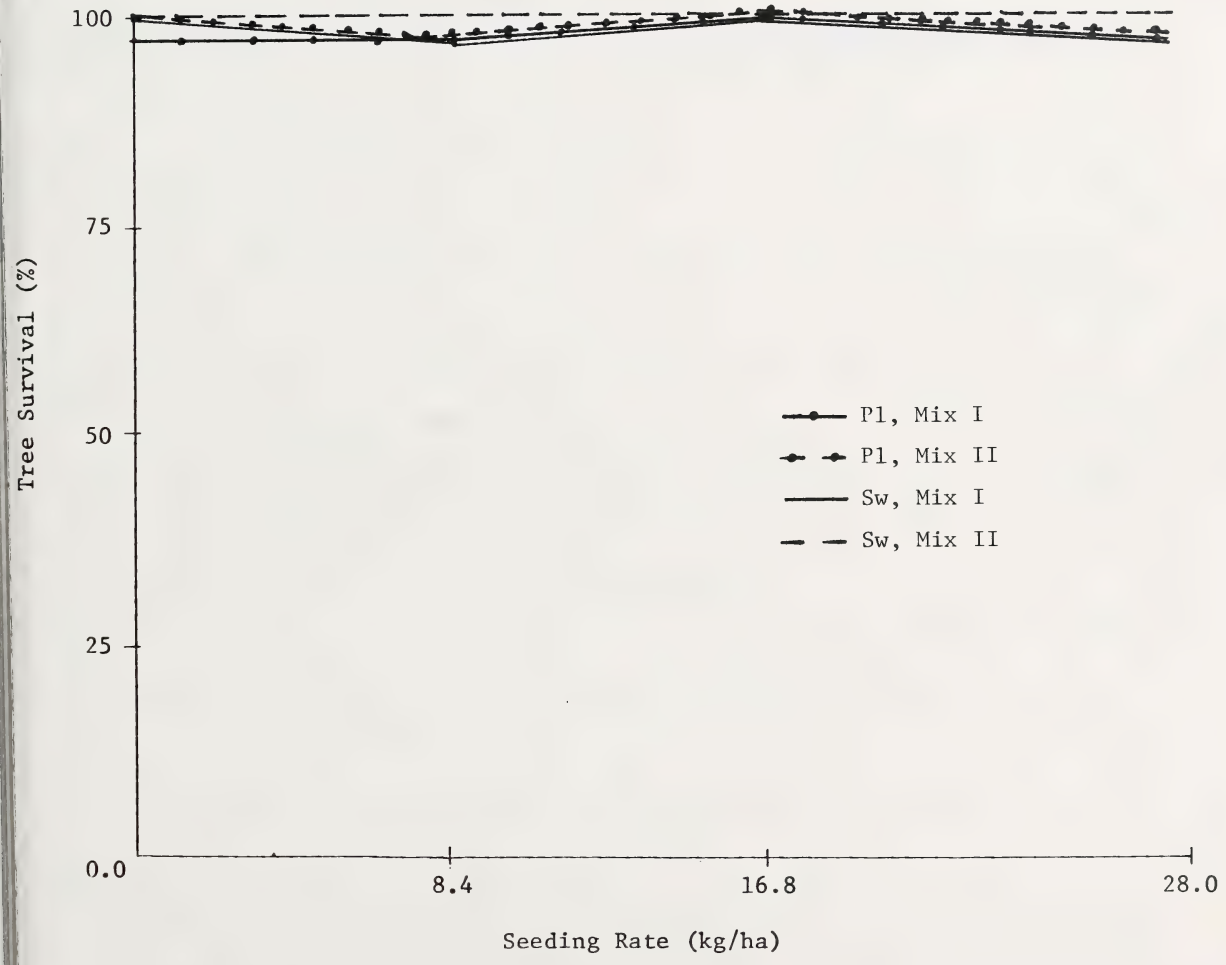
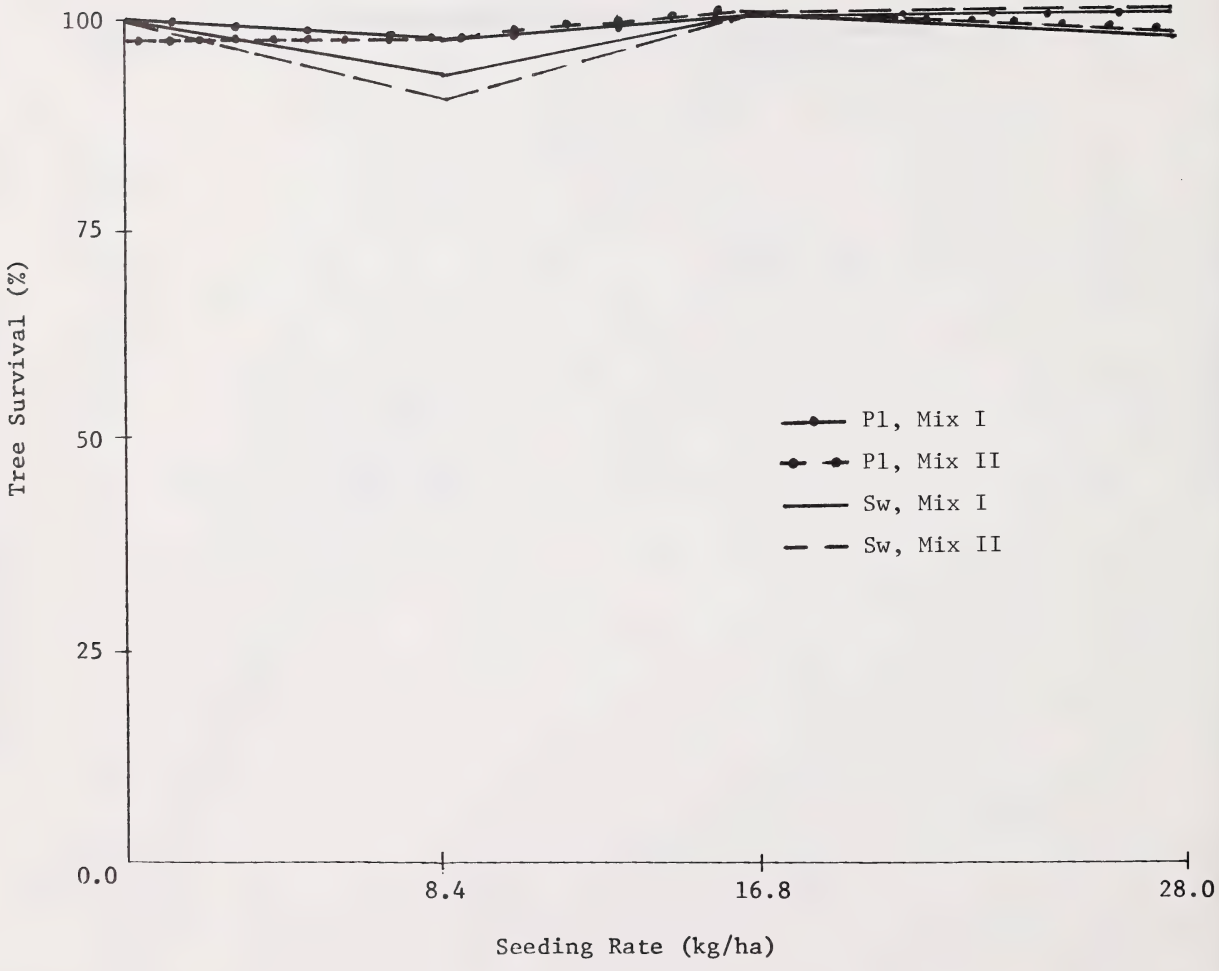


Figure 6

LYNX CREEK TREE SURVIVAL (1983)



will not influence survival performance. Other studies have found that competition may increase the mortality of associated trees (Baron 1962; Clark and McLean 1975; Duffy 1974; Eis 1967; Eis 1981; Fedkenheuer, Heacock and Lewis 1980; Hay and Woods 1980; Vogel 1980). It appears that short-term woody plant mortality in such situations is at least partly the result of fairly extreme, competition - induced soil drought (Day 1963; Day 1964; Eis 1965; Fedkenheuer, Heacock and Lewis 1980).

The Fairfax Lake height increment for 1983 and the three-year cumulative height increment (1981-83) are given in Figures 7 and 8, respectively. For both, the height growth performance was independent of grass and legume factors; neither mixtures nor their application rates influenced height increment. No grass-legume competitive influence is apparent for annual and cumulative height increments at Fairfax Lake, although the growth of lodgepole pine was greater than that of white spruce. The independence of annual height increment from grasses and legumes and dependence on tree species were also observed in 1982 (King 1983).

The Lynx Creek height growth data is presented in Figures 9 and 10. Mixtures did not affect the 1983 annual or 1981-83 cumulative height increments. However, height growth was dependent on seeding rate; increment was greatest on the weeded controls while being suppressed on seeded treatments. Additionally, pine height growths were more than those of spruce. Even though interactive differences in the grass-legume production occurred among some treatments at this site, their effects on tree height growths were not apparent. The grasses and legumes competitively decreased the tree height growth performacne relative to the controls.

Figure 7
FAIRFAX LAKE TREE HEIGHT INCREMENT (1983)

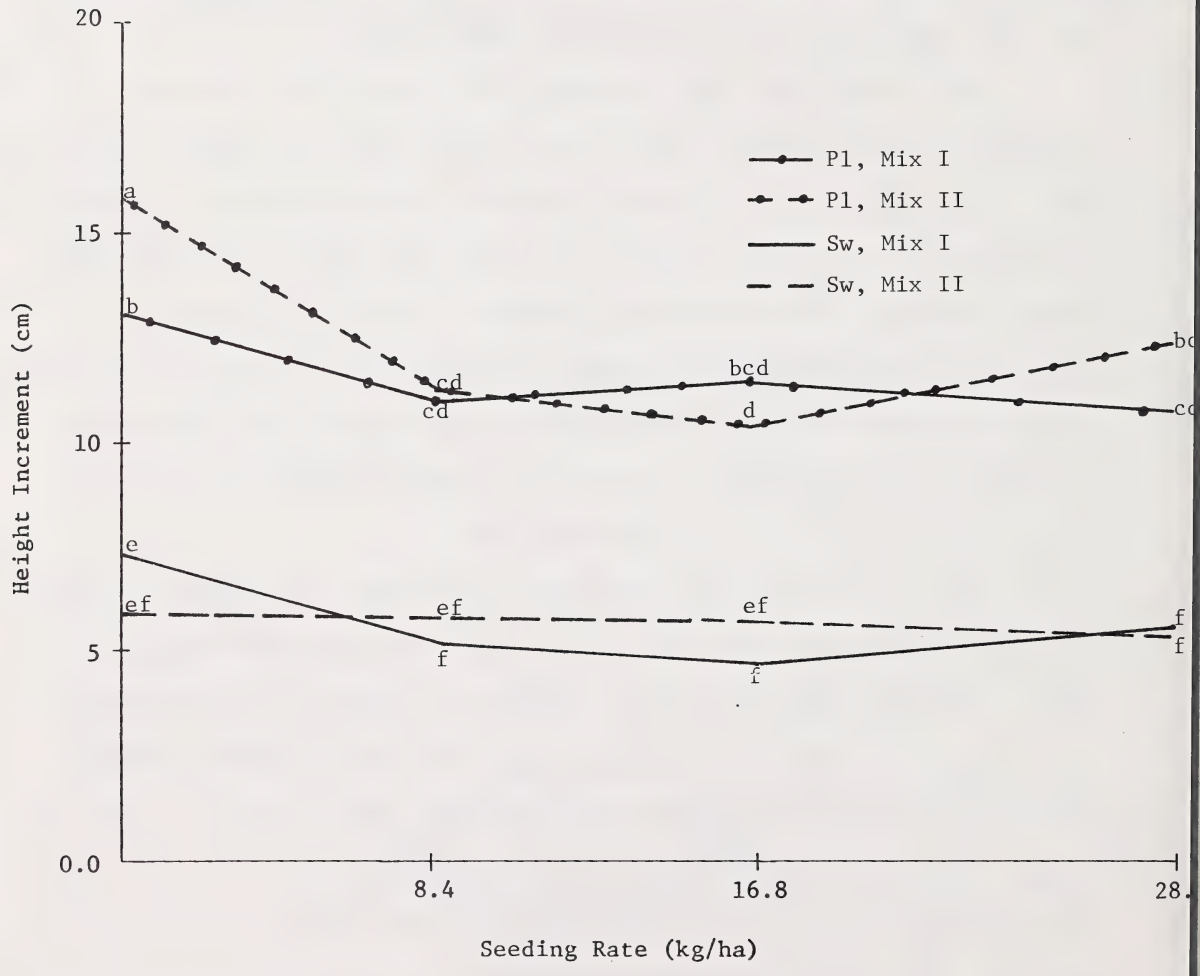


Figure 8

FAIRFAX LAKE CUMULATIVE TREE HEIGHT INCREMENT (1981-83)

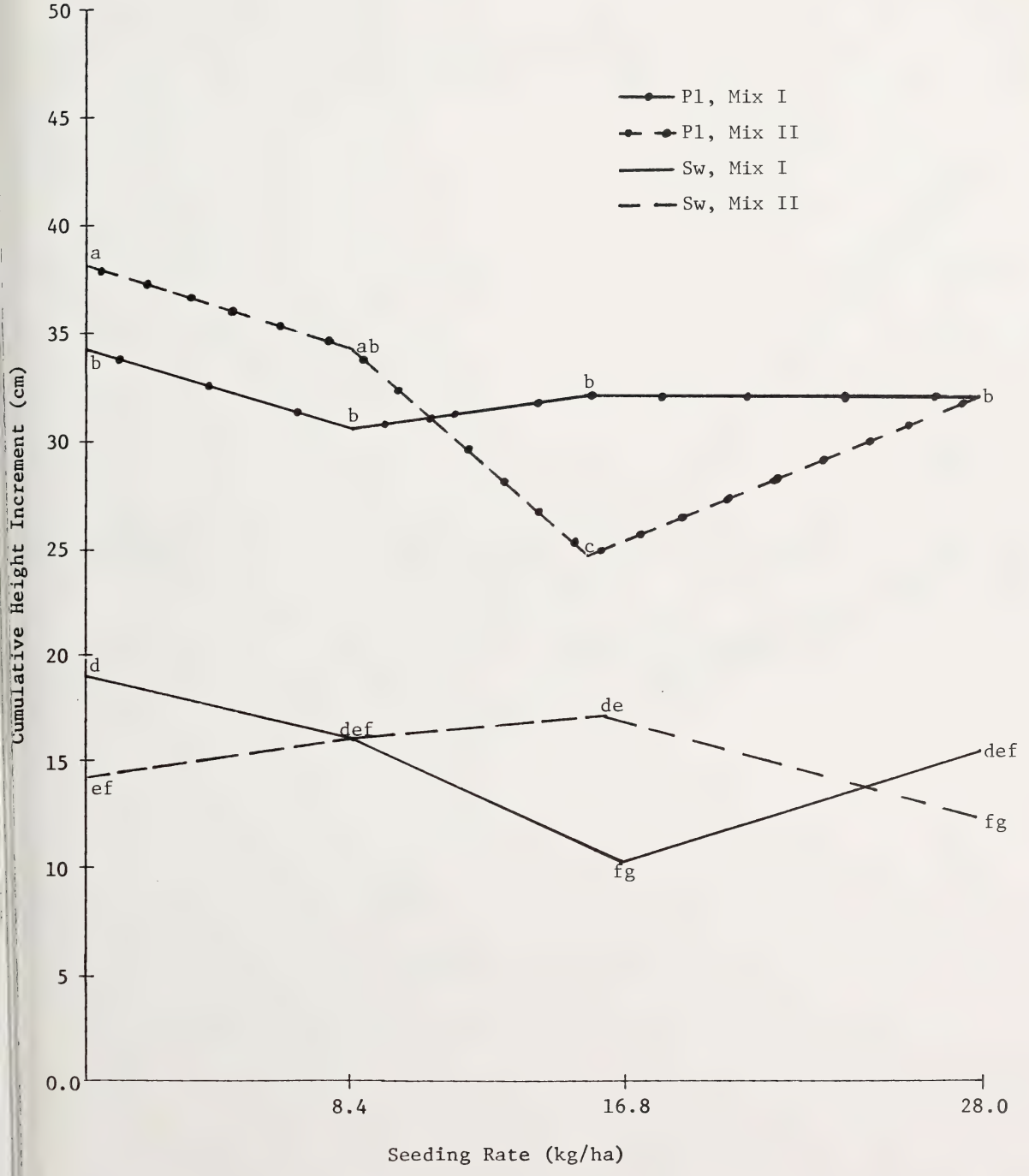


Figure 9

LYNX CREEK TREE HEIGHT INCREMENT (1983)

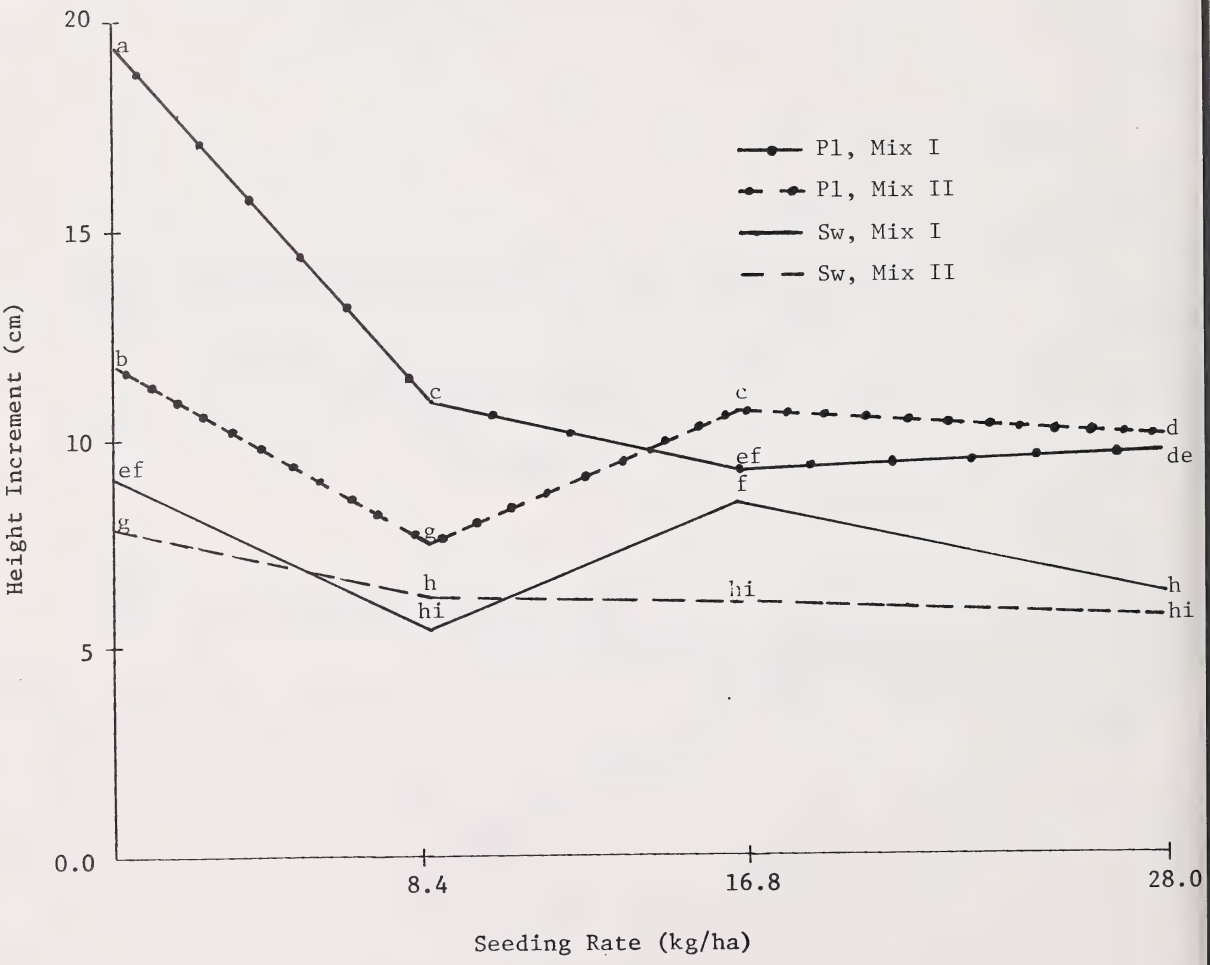
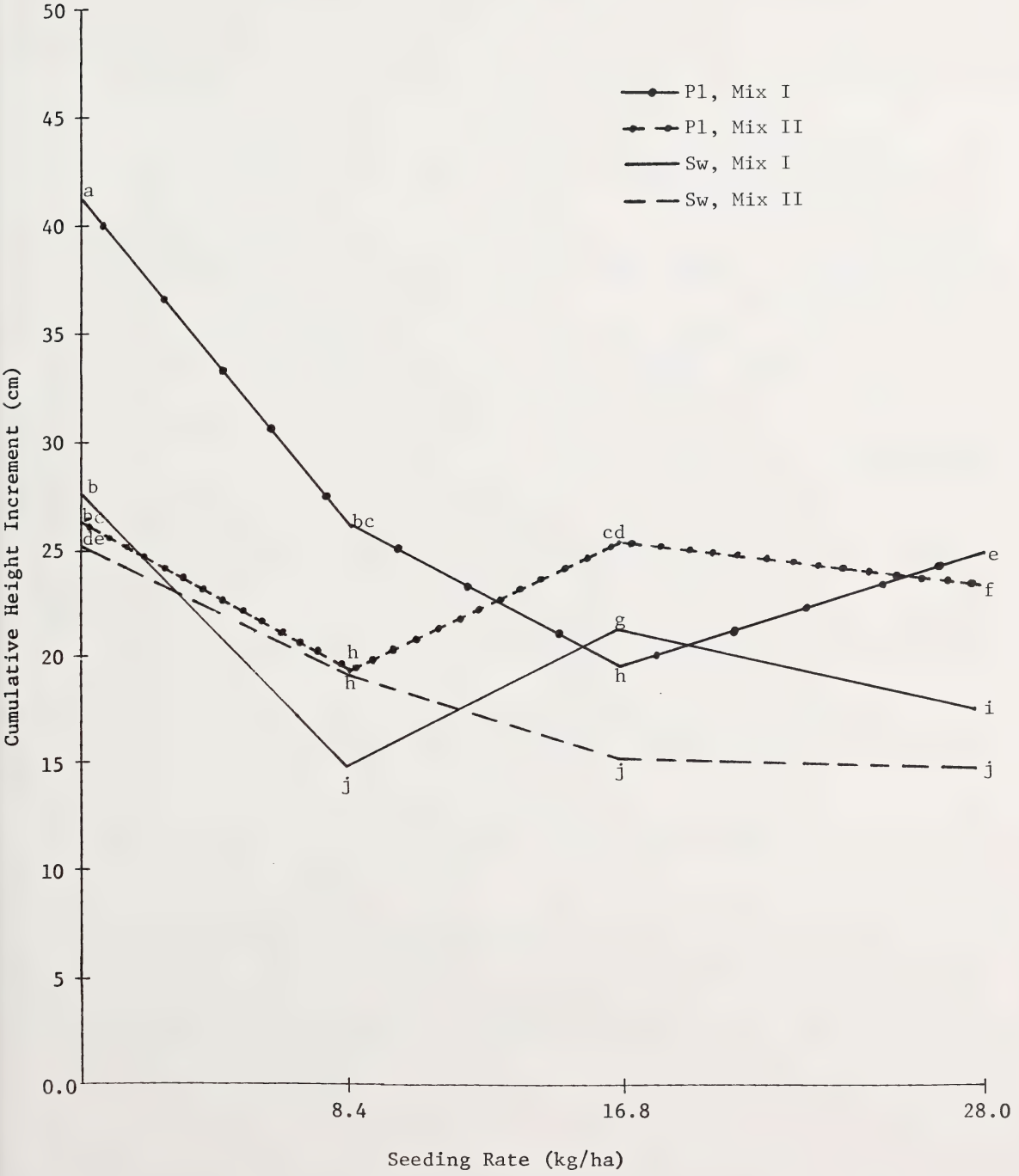


Figure 10

LYNX CREEK CUMULATIVE TREE HEIGHT INCREMENT (1981-83)



The differences in height increments between the two sites may be the result of the reduction of soil moisture by competition and induction of plant moisture stress at Lynx Creek but not at Fairfax Lake. Research carried out by Day (1963) in the Lynx Creek valley documented the local importance of low relative humidity, strong winds and low and irregular precipitation in drying soil and creating soil drought, thus causing adverse early performance of white spruce. Further, the relationship among high levels of competition, low soil moisture and suppression of growth has been reported for white spruce and jack pine (Eis 1967; Eis 1981; Sims and Mueller-Dombois 1968). Seedling growth of many lodgepole pine provenances has been found to cease at plant water potentials ranging from -10 to -15 bars and to be adversely affected when the potentials have been reduced below -2 bars (Dykstra 1974).

The tree stem diameter increments at Fairfax Lake are given in Figures 11 and 12. Both the annual diameter increment in 1983 and the cumulative diameter increment during the 1981-83 period were dependent on tree species with the diameter growth of spruce being less than that of pine. The annual diameter growth was independent of grass-legume treatments while the three-year cumulative growth was affected by the rate of mixture application. Averaged for tree species and grass-legume mixtures, the cumulative diameter growth on the controls was greater than in the seeded plots. Grass and legume mixes did not influence three-year diameter growth.

In the analysis of Lynx Creek annual tree stem diameter increment (Figure 13), growth was affected by tree species, grass-legume seed application rates nad grass-legume mixtures. The stem growth of lodgepole pine was greater than that of white spruce. On plots seeded at 8.4, 16.8

Figure 11

FAIRFAX LAKE TREE STEM DIAMETER INCREMENT (1983)

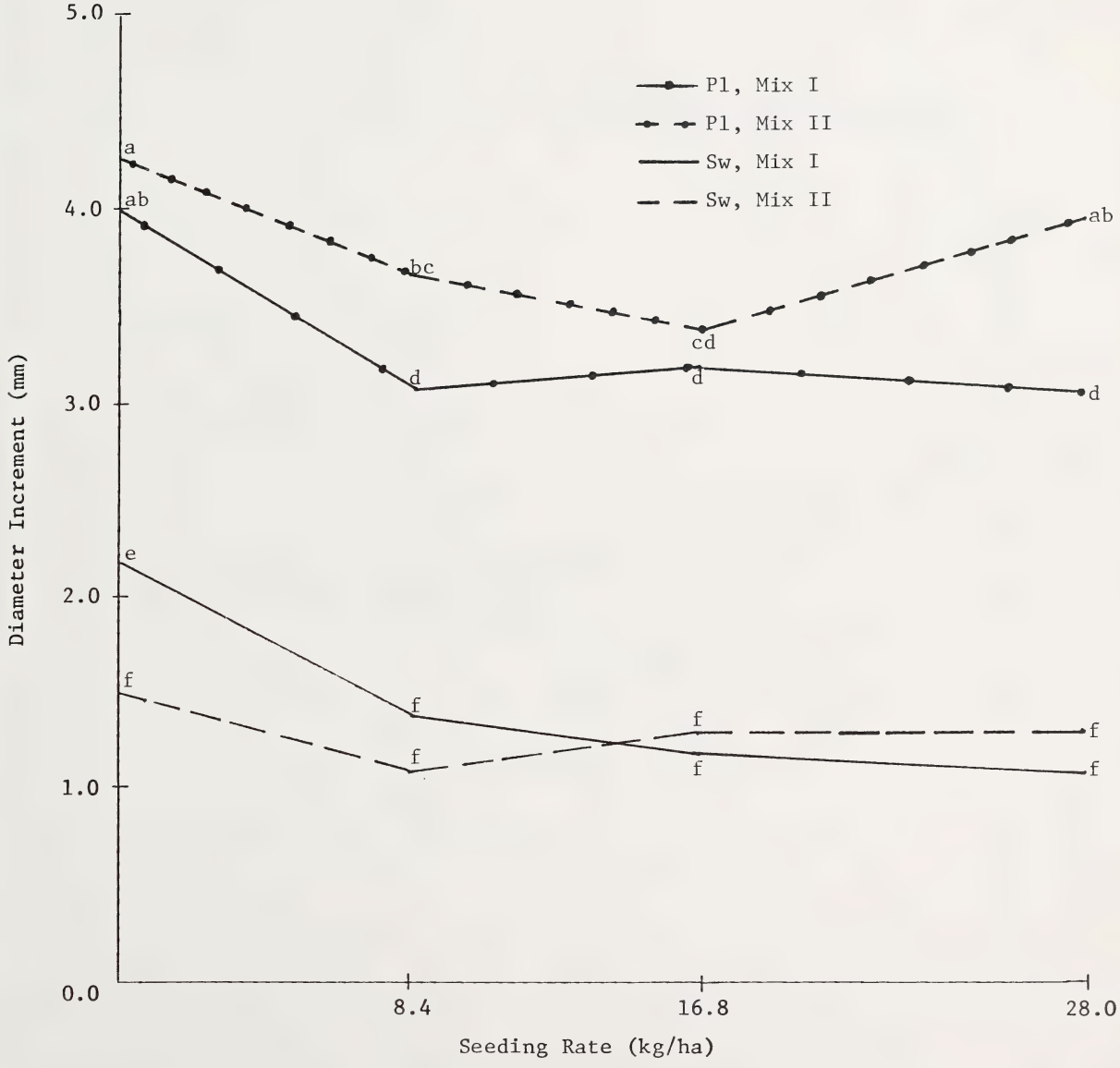


Figure 12

FAIRFAX LAKE CUMULATIVE TREE STEM DIAMETER INCREMENT (1981-83)

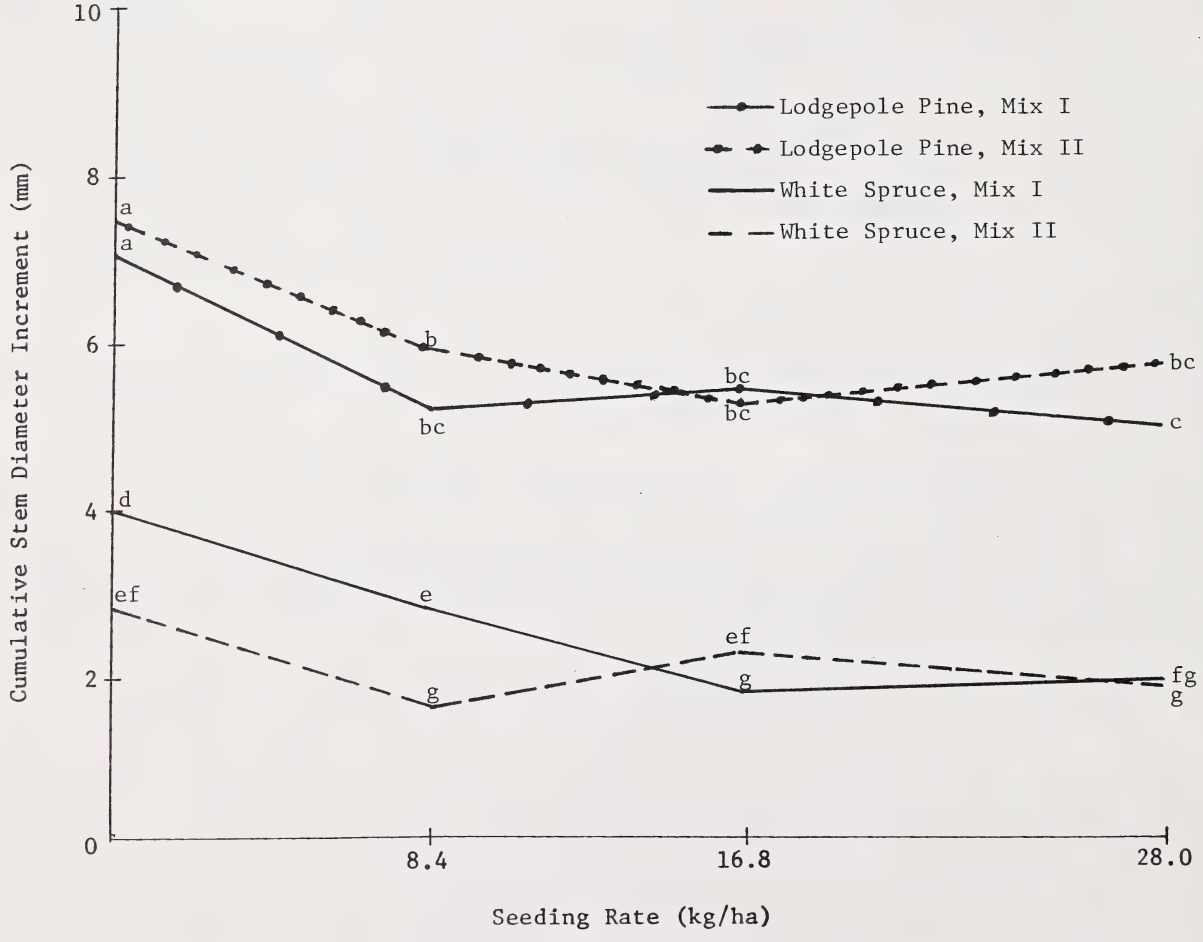
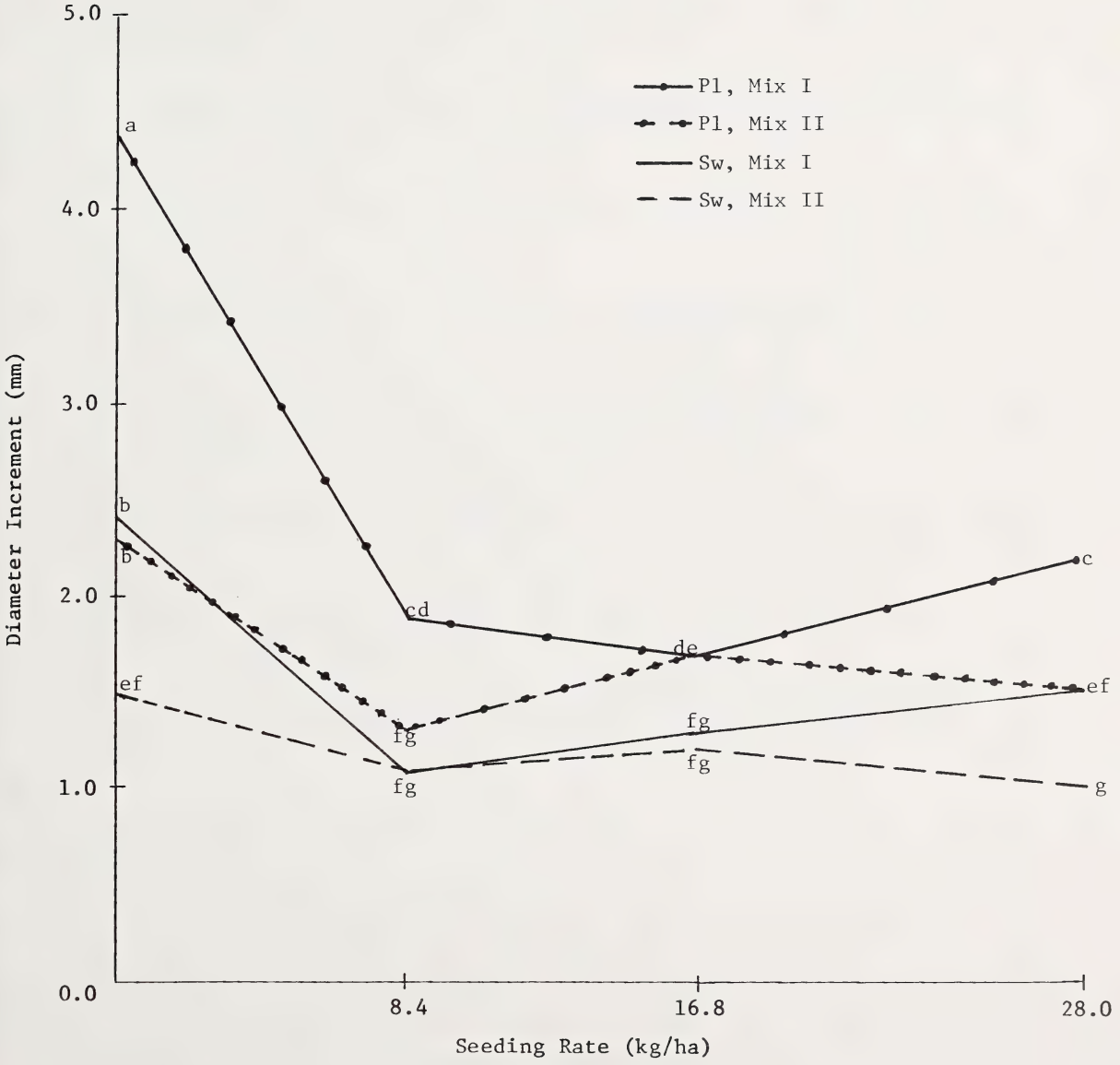


Figure 13

LYNX CREEK TREE STEM DIAMETER INCREMENT (1983)



and 28.0 kg/ha, the growth was suppressed relative to the unseeded and weeded plots. The growth in Mix I was greater than in Mix II. However, this last effect is inconsistent with the results obtained in 1982 for stem annual diameter increment (King 1983) and it is felt that the significant mixture effect was largely due to a confounding influence from the lower levels of grass-legume production in the Mix I controls than in those for Mix II. The sum of Mix I diameter growth at the 0.0 kg/ha rate, across tree species, represented approximately one-quarter of the total experimental sum.

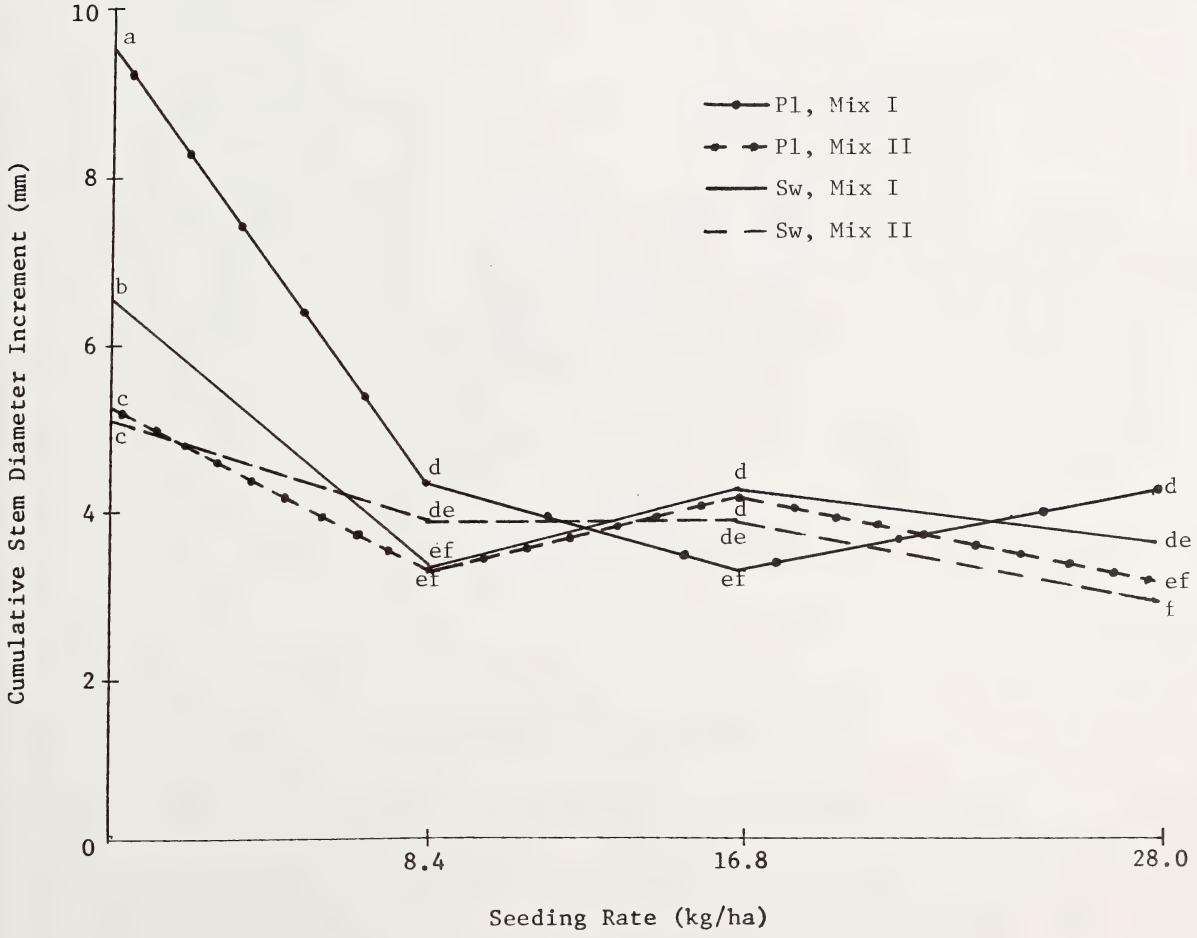
Lynx Creek cumulative tree stem growth is presented in Figure 14. The analysis indicates that the diameter growth over the 1981-83 period was the result of grass-legume application rate and mixture treatments. Increment in the controls was greater than in seeded plots with growth in Mix I being more than in Mix II. As discussed above, the significant mixture effect may be due to confounding.

In the early stages of tree development, the importance of stem diameter is largely restricted to its influence on plant "sturdiness". Even though a grass and legume competitive effect appeared for annual and cumulative diameter increment at Lynx Creek and cumulative growth at Fairfax Lake, it may not be of practical importance unless the suppression were to persist and be of sufficient magnitude to reduce tree bole strength.

A fairly consistent grass and legume competitive effect on interplanted trees was apparent at the Lynx Creek site. Lodgepole pine and white spruce planted into such ground covers exhibited decreased growth performance as compared to the controls. Competition was not observed at Fairfax Lake excepting cumulative diameter increment for a three-year period.

Figure 14

LYNX CREEK CUMULATIVE TREE STEM DIAMETER INCREMENT (1981-83)



Grass-legume treatments did not affect pine and spruce survival at either site. The competition at Lynx Creek is likely due to induced moisture deficits.

4. CONIFEROUS SPECIES DEMONSTRATIONS ON COAL MINE SPOIL

4.1 Methods

Bareroot lodgepole pine and white spruce and containerized white spruce, all grown at the Alberta Provincial Tree Nursery, were planted in 1973 at Lovett and Grassy Mountain. At Lovett, a cover crop composed of creeping red fescue, Nordan crested wheatgrass, timothy and white clover was sown at the time of tree planting. The demonstration at Grassy Mountain was composed of three sites and no cover crops were established. On both sites, the trees were planted into untopsoiled mine spoil. Table 6 summarizes the information for the demonstrations.

The demonstrations were assessed in late summer of 1973 and 1978, at the end of the first and sixth growing seasons, respectively. The data presented is for survival.

4.2 Results and Discussion

Table 7 presents the survival data for the two demonstrations. The survival of lodgepole pine and white spruce bareroot stock at the Lovett site was high six seasons after planting while that of the containerized white spruce was poor. In comparison, the sixth-year mortality of all stock was high at Grassy Mountain. Grassy Mountain's bareroot pine

Table 6

SITE AND PLANTING INFORMATION FOR CONIFEROUS DEMONSTRATIONS

Demonstration	Location	Elevation (m)	Coniferous Tree Species Established	Seeded Cover Crop
Lovett	SW 16-47-19-W5	1 372	lodgepole pine (bare-root) white spruce (bare-root) white spruce (2.5 in^3 container)	creeping red fescue, Nordan crested wheatgrass, timothy, white clover
Grassy Mountain (Three Sites)	NE 23-8-4-W5 SW 25-8-4-W5 NE 25-8-4-W5	1 585 1 646 1 890	lodgepole pine (bare-root) white spruce (bare-root) white spruce (2.5 in^3 container)	none

Table 7

SURVIVAL IN CONIFEROUS DEMONSTRATIONS

Demonstration	Species	Type of Stock	Average Survival (%)	
			After One Growing Season	After Six Growing Seasons
Lovett	lodgepole pine	bareroot	96	94
	white spruce	bareroot	98	84
	white spruce	container	78	18
Grassy Mountain				
Site 1 (el. 1 585 m)	lodgepole pine	bareroot	36	13
	white spruce	bareroot	84	38
Site 2 (el. 1 646 m)	lodgepole pine	bareroot	66	31
	white spruce	bareroot	79	-
	white spruce	container	78	27
Site 3 (el. 1 890 m)	lodgepole pine	bareroot	35	22
	white spruce	bareroot	68	37
	white spruce	container	31	6
All sites	lodgepole pine	bareroot	46	22
	white spruce	bareroot	73	37
	white spruce	container	43	11

survival averaged 22 percent, white spruce bareroot 37 percent and white spruce container stock 11 percent.

The poor survival at the Grassy Mountain site may be attributed to any of a number of factors. Among these are:

1. The effects of soil drying in the area, as discussed in Section 3.2, combined with the planting of trees directly into spoil materials, may have created critical sub-optimal levels of available soil water and resulted in tree mortality, even without a competing grass-legume cover crop having been established. The use of topsoiling may have alleviated the problem.

2. Without the use of any cover crop or other form of microsite protection, the seedlings were fully exposed to light. The adverse effects of such exposure on survival have been reported for white spruce (Day 1964) and Engelmann spruce (Ronco 1970). Full exposure is less critical in lodgepole pine survival (Satterlund 1973).

3. The effects of wind and blasting by saltant spoil particles may have been severe enough to damage and weaken the trees, making them more susceptible to mortality. The use of a cover crop in a configuration which minimizes competition would have reduced the blasting effects.

5. CONCLUSIONS

5.1 Exotic Tree and Shrub Demonstrations

Exotic woody plant species including buffaloberry, Northwest poplar, caragana and Siberian elm may be candidates for use in reclamation in the Eastern Slopes. However, the use of non-native species would not generally be advisable for reclamation to wildland-oriented uses. The demonstrations indicate that amelioration of mine spoil may be necessary in southwestern Alberta.

5.2 Influence of Grasses and Legumes on the Performance of Inter-planted Coniferous Trees

A consistent competitive effect of seeded grass and legume mixtures on the growth performance of inter-planted trees was observed in the trial located in the southern foothills, while little effect was evident in the central foothills. Competition did not influence tree survival at either site. As ground covers are necessary for erosion control, reclamation practice may have to be modified to minimize grasses and legumes on and adjacent to tree planting spots. The results of the experiments raise a concern that tree stocking surveys alone may not be an adequate measure of regeneration success when competitive ground cover is present. The addition of a "free-to-grow" measurement may be prudent and should certainly be examined further.

5.3 Coniferous species Demonstrations on Mine Spoil

The survival of lodgepole pine and white spruce bareroot stock was high at Lovett (central foothills) and low at Grassy Mountain (southern foothills), while the mortality of white spruce containerized stock was high at both sites. The comparatively low overall survival at the southern foothills sites is likely due to greater soil drying and indicates the need for site amelioration in the area.

LITERATURE CITED

Baron, F. 1962. Effects of Different Grasses on Ponderosa Pine Seedling Establishment. U.S.D.A. Forest Service, Pacific Southwest Forest and Range Experiment Station. Berkely, California. Report No. 199. 8 pp.

Clark, M. and A. McLean. 1975. Growth of Lodgepole Pine Seedlings in Competition with Different Densities of Grass. British Columbia Forest Service. Victoria, British Columbia. Research Note No. 70. 10 pp.

Day, R. 1963. Spruce Seedling Mortality Caused by Adverse Summer Microclimate in the Rocky Mountains. Canada Department of Forestry, Forest Research Branch. Ottawa, Ontario. Publication No. 1003. 36 pp.

_____. 1964. The Microenvironments Occupied By Spruce And Fir Regeneration in the Rocky Mountains. Canada Department of Forestry, Forest Research Branch. Ottawa, Ontario. Publication No. 1037. 21 pp.

Duffy, P. 1974. Planting grass and pine for erosion control. Tree Planters Notes. 25(1): 10-13.

Dykstra, G. 1974. Drought Resistance of Lodgepole Pine Seedlings in Relation to Provenance and Tree Water Potential. British Columbia Forest Service. Victoria, British Columbia. Research Note No. 62. 12 pp.

Eis, S. 1965. Development of white spruce and alpine fir seedlings on cut-over areas in the central interior of British Columbia. Forestry Chronicle. 41: 419-431.

_____. 1967. Establishment and early development of white spruce in the interior of British Columbia. Forestry Chronicle. 43: 174-177.

_____. 1981. Effect of vegetative competition on regeneration of white spruce. Canadian Journal of Forestry Research 11(1): 1-8.

Fedkenheuer, A., H. Heacock and D. Lewis. 1980. Early performance of native shrubs and trees planted on amended Athabasca oil sands tailings. Reclamation Review. 3(1): 47-55.

Hay, R. and F. Woods. 1980. Minesite Preparation for Reforestation of Strip-Mined Lands. U.S. Environmental Protection Agency. Cincinnati, Ohio. Report No. EPA-600/7-80-005. 23 pp.

King, P. 1983. Influence of Agronomic Grass-Legume Mixtures on the Performance of Commercial Softwood Tree Species Used in Reclamation. In: Proceedings of the Eighth Annual Meeting, Canadian Land Reclamation Association. Waterloo, Ontario. August 21-24, 1983. (In Press)

Ronco, F. 1970. Influence of high light intensity on survival of planted Engelmann spruce. Forest Science. 16: 331-338.

Sims, P. and D. Mueller-Dombois. 1968. Effect of grass competition and depth of water table on height growth of coniferous tree seedlings. Ecology. 49(4): 597-603.

Satterlund, D. 1973. Climatic Factors and Lodgepole Pine. In: Symposium Proceedings, Management of Lodgepole Pine Ecosystems. Pullman, Washington. October 9-11, 1973. 297-309.

Vogel, W. 1980. Revegetating Surface-Mined Lands with Herbaceous and Woody Species Together. In: Proceedings, Trees for Reclamation in the Eastern U.S. Lexington, Kentucky. October 27-29, 1980. 117-126.

CURRENT RESEARCH ON SEEDLING GROWTH AT OBED MARSH

OBED MOUNTAIN COAL COMPANY LIMITED

T. A. B. ADAMSON, P. AG.

MAY 2, 1984

PAPER TO BE PRESENTED MAY 2, 1984 AT RRTAC WORKSHOP ON

REVEGETATION METHODS FOR THE MOUNTAINS AND FOOTHILLS

CURRENT RESEARCH ON SEEDLING GROWTH AT OBED MARSH

INTRODUCTION

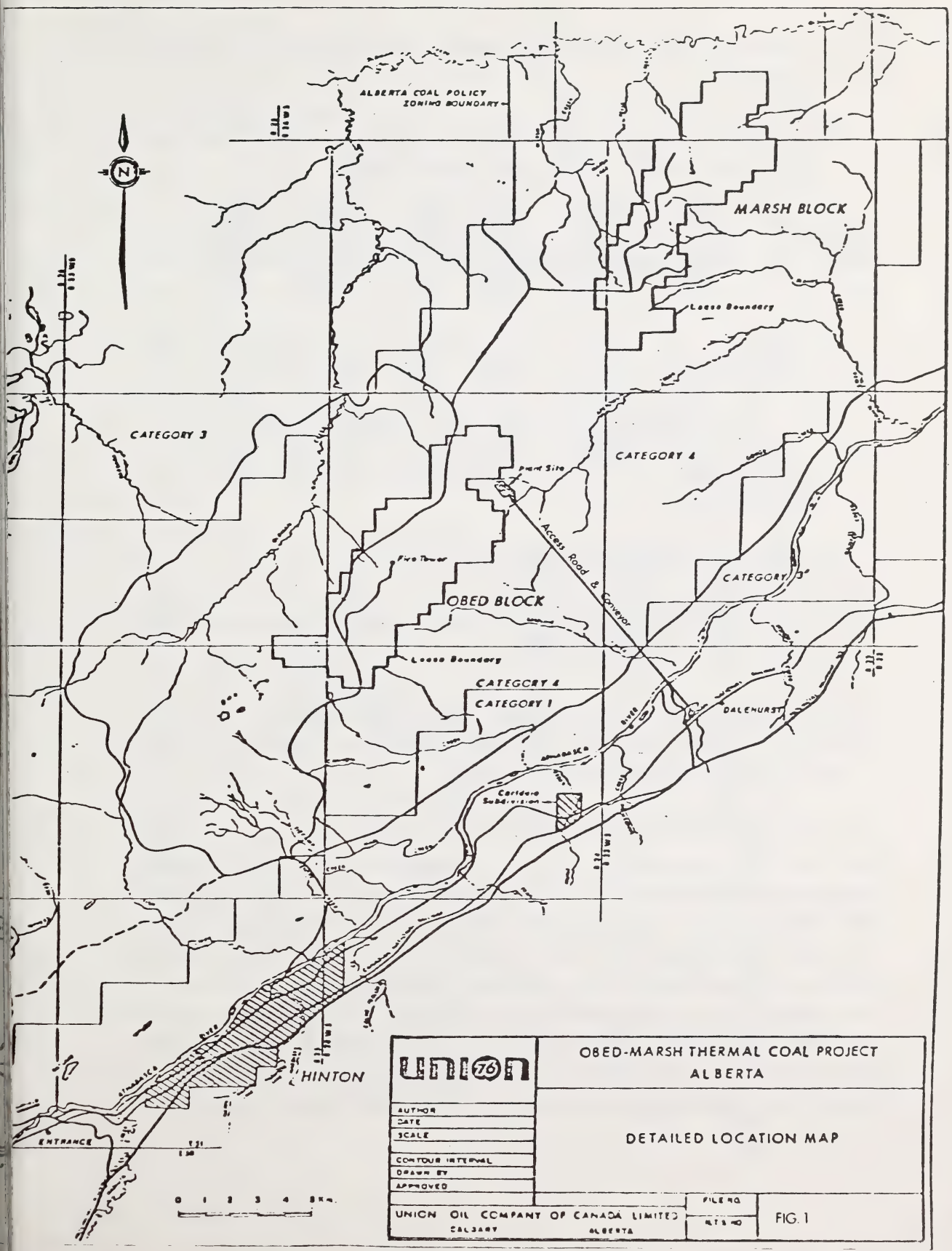
My alloted twenty minutes is too short a time to be able to discuss our test plot programme in detail. What I propose to do, therefore, is to provide you with some background information leading to a statement of purpose for which the plots were constructed; briefly provide you with the statistical designs and our field construction before describing the field measurements that we take. The last few minutes of my talk will be devoted to describing the main trends we have seen to date at Obed, as illustrated by our 1983 results. I am not going to describe in detail our plots measuring the influence of aspect or seeding of grass on the young seedlings. I will, however, mention some of the pertinent data.

Please bear in mind that our end land use objective at Obed Mountain is to return the site to commercial forestry using white spruce and lodgepole pine. A site location map showing the lease area in relation to Hinton is given in Figure 1. This is a relatively high area reaching 1,650m at its highest point.

BACKGROUND

Like the proposed Mountain - Foothills Reclamation Research Programme, before proceeding with any work we undertook a literative survey on what was known about spruce and pine growing at sites similar to Obed. Whilst this was not a definitive study, I believe the main conclusions reached can be considered as such. Our conclusions were:

1. There was little known about the physical, chemical or biological requirements of white spruce or lodgepole pine growing on the OBED lease.


ALBERTA COAL POLICY ZONING BOUNDARY
MARSH BLOCK
Lease Boundary
CATEGORY 3
CATEGORY 4
Plant Site
Access Road & Conveyor
Fire Tower
OBED BLOCK
CATEGORY 3
Lease Boundary
CATEGORY 4
CATEGORY 1
DALEHURST
Caribou Subdivision
HINTON
ENTRANCE
0 1 2 3 4 5 Km.
union 76
OBED-MARSH THERMAL COAL PROJECT
ALBERTA
AUTHOR
DATE
SCALE
CONTOUR INTERVAL
DRAWN BY
APPROVED
DETAILED LOCATION MAP
UNION OIL COMPANY OF CANADA LIMITED
CALGARY ALBERTA
FILE NO.
FIG. 1

2. About 6% - 10% available moisture is needed in the soil for spruce or pine.

3. Low soil temperatures, related to moisture content and slash covering, probably inhibit tree growth at OBED.

Before plots were designed we identified several objectives based on this information, which we considered needed answering by the test plots. These are:

1. Determine and monitor characteristics of reconstructed soil profiles.

2. Provide a simulated post-mining site to monitor seedling establishment and growth in relation to soil moisture and temperature.

3. Determine influence of slash cover on above.

4. Help decide feasible methods of slash removal, storage, and return in relation to the mine plan.

In the early years during the pre-mining development stage, objective 4 was undoubtedly the most important. Now that mining has commenced objectives 1, 2 and 3 have assumed greater importance.

Once the objectives are known it is a relatively easy step to design statistically sound plots. By this approach we felt that personal judgements based on experience could be omitted during the crucial phase of data interpretation. The design used for the main plots is shown in figure 2 - three replications with one reference site. Please learn from our mistake, we should ideally have replicated the reference plot as well. By this design you can see that we are comparing two different surface treatments (T1 and T2) as measured by the performance of spruce and pine. This helped us fulfill objective 4 mentioned previously. You can also see that we took detailed soil samples so that we could fulfill objective 2.

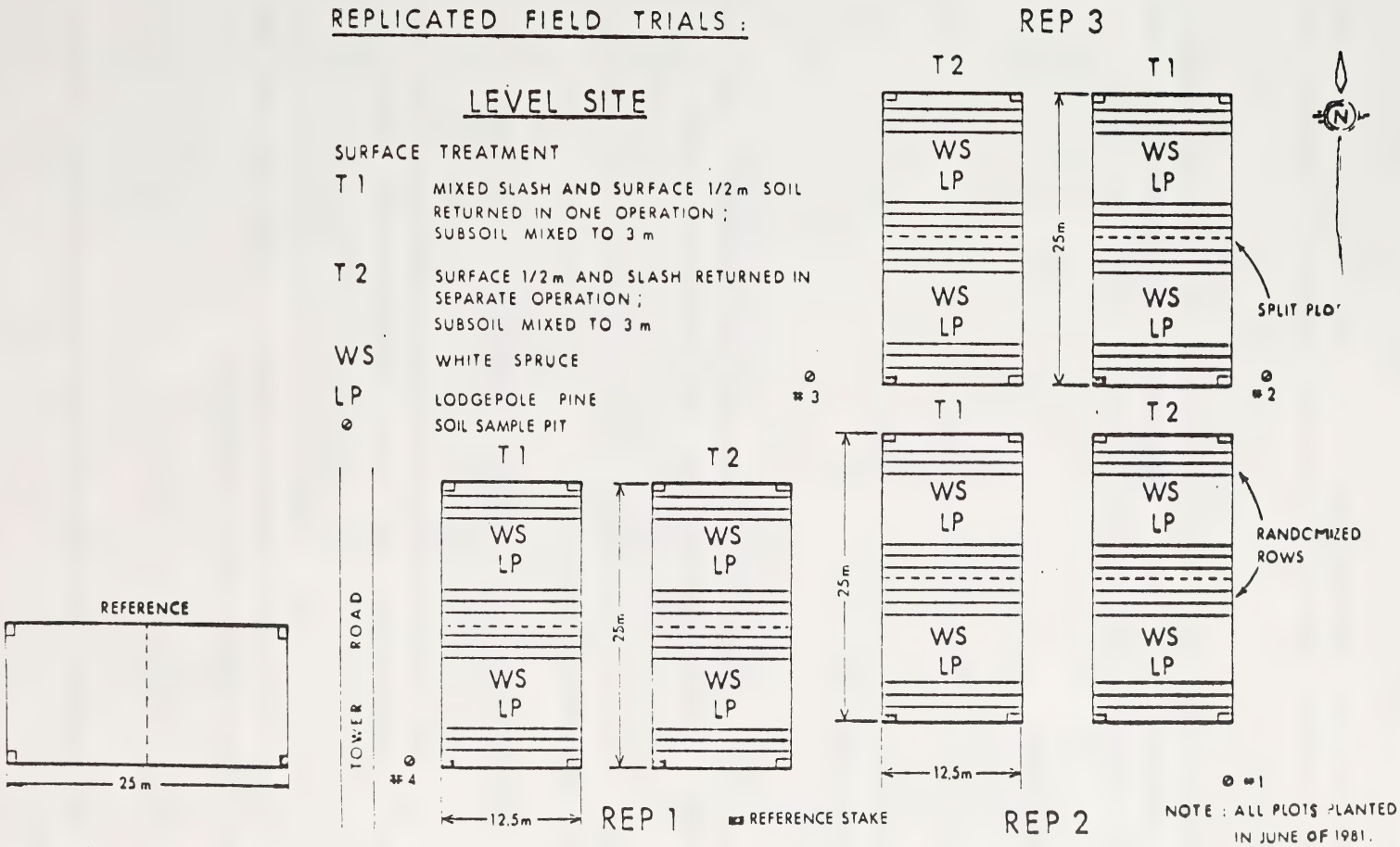

REPLICATED FIELD TRIALS :
REP 3
LEVEL SITE
SURFACE TREATMENT
T 1 MIXED SLASH AND SURFACE 1/2 m SOIL RETURNED IN ONE OPERATION ; SUBSOIL MIXED TO 3 m
T 2 SURFACE 1/2 m AND SLASH RETURNED IN SEPARATE OPERATION ; SUBSOIL MIXED TO 3 m
WS WHITE SPRUCE
LP LODGEPOLE PINE
SOIL SAMPLE PIT
T 2
T 1
WS
LP
25m
SPLIT PLOT
#3
#2
T 1
T 2
RANDOMIZED ROWS
REFERENCE
25 m
TOWER ROAD
#4
12.5m
REP 1
REFERENCE STAKE
REP 2
#1
NOTE : ALL PLOTS PLANTED IN JUNE OF 1981.

FIG. 2

In addition to this we put in permanent soil moisture and temperature cells (objective 2) in the locations shown in figure 3. A total of 24 cells were established on these replicated plots as that was the number I considered sufficient to take acount of the natural variation of these two soil parameters.

In addition to these plots we also established plots of a similar design; one on a north aspect and one on a south aspect. These plots also included a seeding treatment and are referred to as the north and south plots.

FIELD MEASUREMENTS

Until the spring of 1983 we measured;

- leader growth
- total height and
- vigour

at the end of the growing season, sometime during September. In addition we monitored the soil temperature and soil moisture on a weekly basis. With the mild winter of 1982 - 1983 we started to do field observations in the spring, in June, to determine the overwinter mortality, in addition to the annual measurements.

The soil temperature and soil moisture is measured by a resistance meter. Although a direct instantaneous reading for soil temperature can be obtained, all soil moisture readings had to be calibrated under controlled conditions in the laboratory. To do this I selected 3 cells randomly, and took some soil samples. In the laboratory the soil was subjected to different moisture levels. Computing resistance (ohms) against soil moisture we get the graph, shown in Figure 4, which has best been described by this equation for Obed conditions:

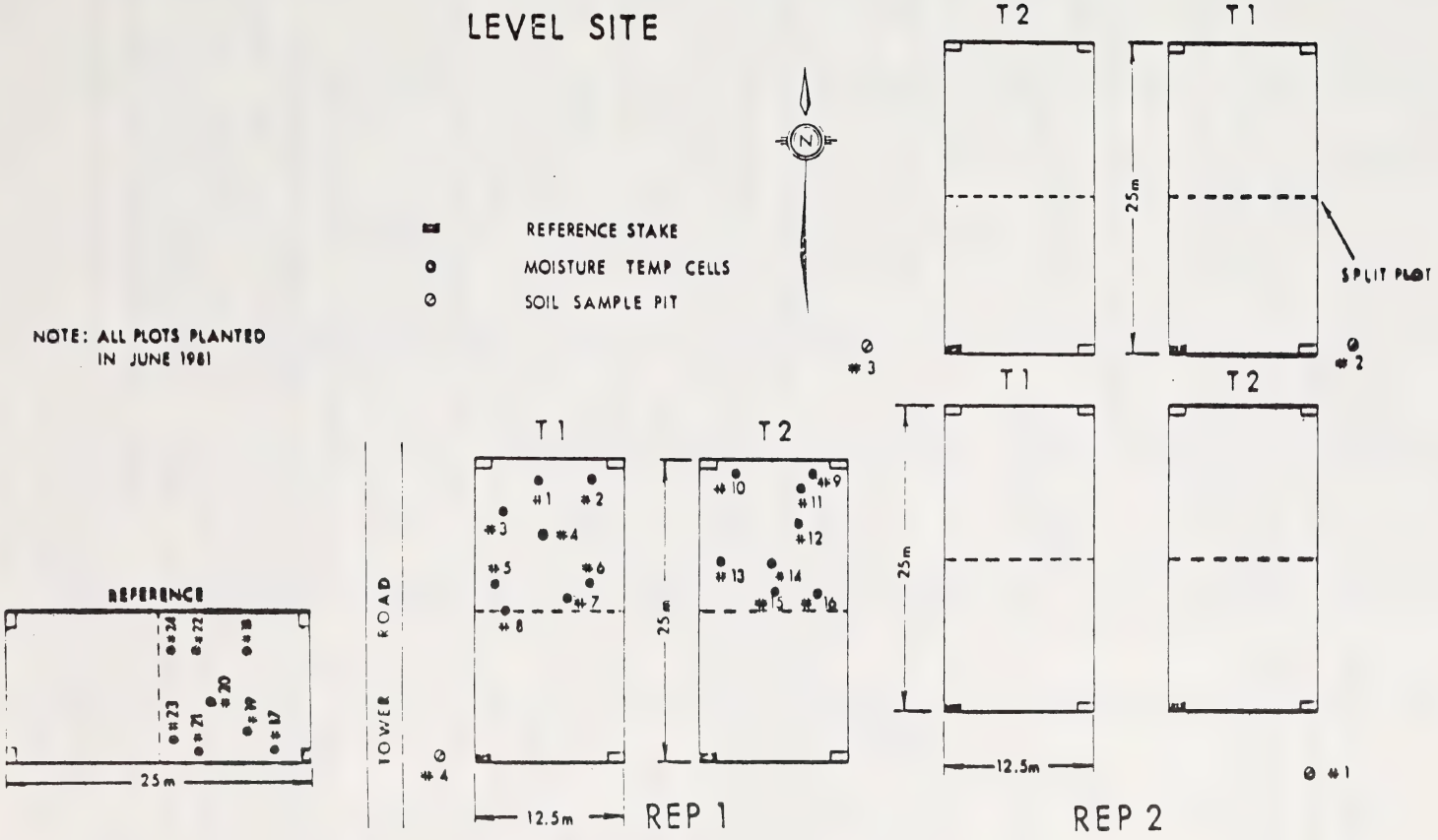
$$\% \text{ moisture} = 1722.8 \, [\text{Log } R]^{-3.0779}.$$

We now have a method for computing soil moisure directly (refer to objective above).

LOCATION OF SOIL MOISTURE/TEMPERATURE CELLS

REPLICATED FIELD TRIALS :

LEVEL SITE



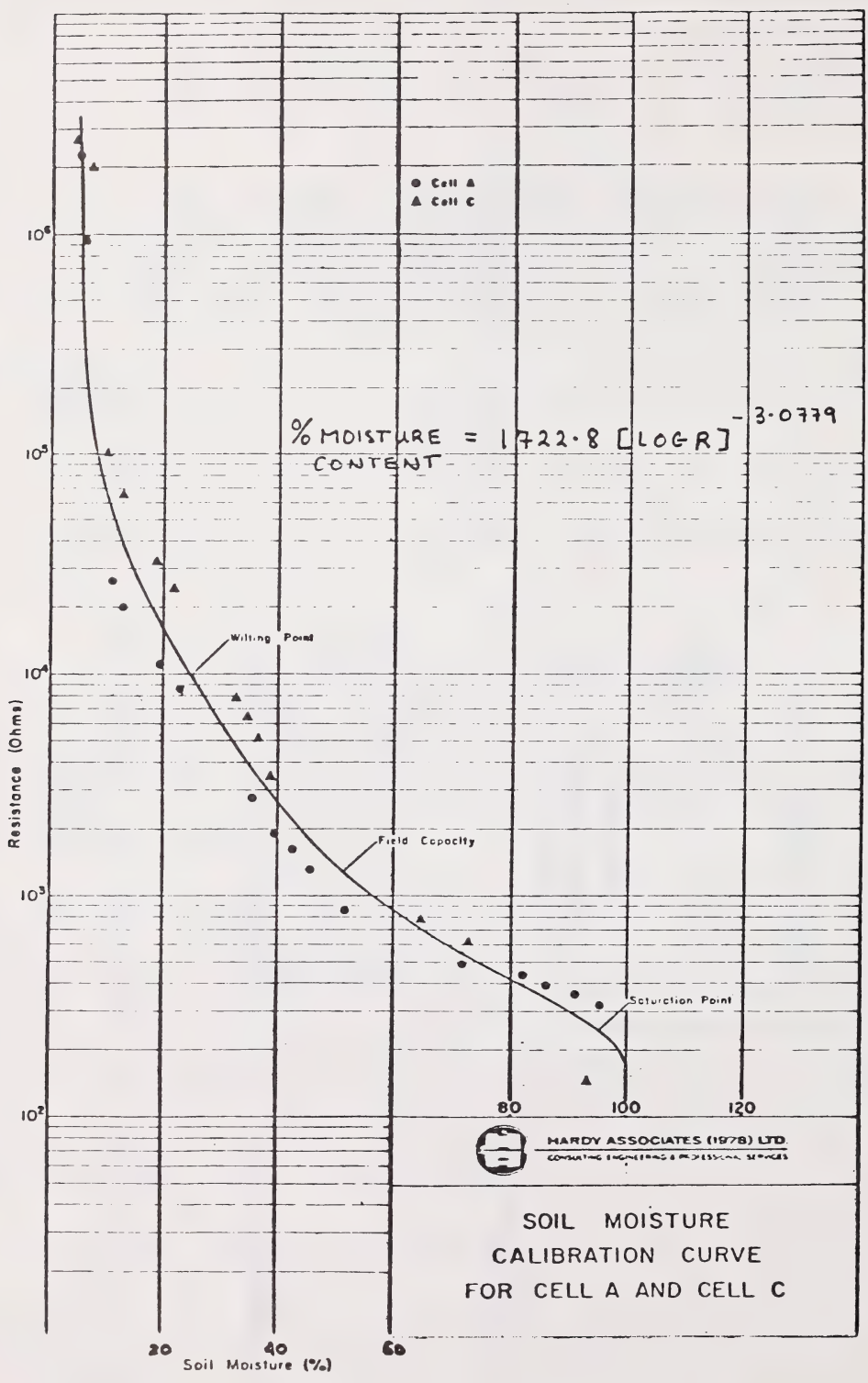

● Cell A
▲ Cell C
% MOISTURE CONTENT = 1722·8 [LOG R]^-3·0779
Wilting Point
Field Capacity
Saturation Point
Resistance (Ohms)
10⁶
10⁵
10⁴
10³
10²
20
40
60
80
100
120
Soil Moisture (%)
HARDY ASSOCIATES (1978) LTD
SOIL MOISTURE
CALIBRATION CURVE
FOR CELL A AND CELL C

FIG. 4

1983 RESULTS

The mild winter of 1982 - 1983 resulted in much of the snow cover being dissipated at Obed and exposing the young seedlings. The only assessment done subjectively is the vigour, where the arbitrary descriptions of excellent, good, fair, poor, very poor, and dead are used. This is based only upon a visual observation of the young seedlings.

Let me now describe some of our 1983 results:

1. TOP BROWNING EFFECT

The exposure of the young seedlings coupled with the mild winter temperatures resulted in the water located in the inter-cellular spaces migrating back into the cell vacuoles. Subsequent freezing resulted in the cell walls breaking and death of that part of the seedling, which then turned brown. This phenomena was observed over the whole mine site and is independent of any surficial treatments. However, over the 3 test plot areas there is a significant difference between the species. A comparison of Table 1 with Table 2 shows that this top browning effect is not very serious until the majority of the seedling has become affected. In this case it can result in the death of the whole seedling. Note that the pine is more susceptible than spruce. Here we have approximately 18% of the pine is dead by the following fall, whereas only 6% of the spruce that had this condition succumbed. Note also that the pine has more in the poor and very poor vigour categories by fall. I did a Chi-square test on these results to test the null hypothesis that spring condition and fall vigour are independent. Obviously, from these figures they are significantly inter-related. The question is why was the pine more affected than the spruce? One answer could be because the pine seedlings were taller than the spruce. Not surprisingly this effect has a statistical effect on subsequent leader growth for both species, i.e. the top browning condition reduces subsequent leader growth. The north slope was most affected, then the south slope and then the level site. There was no significant difference between the treatments T1 and T2.

TABLE 1

Analysis For Fall Vigour In Comparison To Spring Condition For Pine Over The Three Sites

	COUNT / ROW PCT	V3 Dead 0	Excel. 1	Good 2	Fair 3	Poor 4	V. poor 5	ROW TOTAL
O.K.		4 .6	161 24.1	355 53.2	126 18.9	19 2.8	2 .3	667 64.3
T.B.[1]			4 6.3	30 46.9	19 29.7	10 15.6	1 1.6	64 6.2
S.T.B.[2]		58 18.9		26 8.5	60 19.5	78 25.4	85 27.7	307 29.6
	COLUMN TOTAL	62 6.0	165 15.9	411 39.6	205 19.7	107 10.3	88 8.5	1038 100.0

CHI-SQUARE	D.F.	SIGNIFICANCE	MIN E.F.	CELLS WITH E.F.< 5
609.13110	10	0.0	3.823	1 OF 18 (5.6%)

Note 1: TB = Top Browning
Note 2: STB = Serious Top Browning

TABLE 2

Analysis for Fall Vigour In Comparison To Spring Condition For Spruce Over The Three Sites

R3A	COUNT / ROW PCT	Dead 0	Excel. 1	Good 2	Fair 3	Poor 4	V. poor 5	ROW TOTAL
O.K.	0	8 1.1	51 6.8	394 52.7	237 31.7	53 7.1	4 .5	747 74.1
T.B.	21		1 .8	49 40.2	66 54.1	6 4.9		122 12.1
S.T.B.	22	8 5.8	1 .7	22 15.8	58 41.7	41 29.5	9 6.5	139 13.8
	COLUMN TOTAL	16 1.6	53 5.3	465 46.1	361 35.8	100 9.9	13 1.3	1008 100.0

CHI-SQUARE	D.F.	SIGNIFICANCE	MIN E.F.	CELLS WITH E.F.< 5
180.47027	10	0.0	1.573	4 OF 18 (22.2%)

2. MORTALITY

Let us now consider mortality per se. The data given in Table 3 shows that there is no statistical significant difference in mortality rating between the reference site and the treated plots for pine on the level site; there is a difference though for spruce at the 95% confidence level. This difference is also evident on the north and south aspects for spruce. I would like to draw your attention to the significant difference exhibited by both species on the north slope site. This is an exposed site; we believe the results here reflect the fact that the wind protection was removed during plot construction, i.e. the micro sites were not available to protect the young seedlings. Also, by extension, there is no difference in micro site availability between T1 and T2 treatments. (The data in table 4 shows that mortality to date under treatment T2 is almost twice that under treatment T1, and that mortality increases from the level, to the north to the south slope on T2 plots). An analysis of variance (ANOVA) for total mortality to date could only be done for the treated areas, because the reference plot was not replicated. This is a weakness of the design and others contemplating plot establishment should be aware of this. The results from the ANOVA showed that both site and treatment effects were significant at the 95% confidence level. No other effects or interactions are significant at this level, including species.

When we just look at mortality occurring since fall 1983, the same general trends are evident, but the ANOVA test shows that we are getting a significant site x treatment interaction. I believe this possibly arises because of a more significant response to site Treatment T2 than in Treatment T1. This indicates we may have to comtemplate using different management techniques at different sites.

3. LEADER GROWTH AND TOTAL HEIGHT

I also looked at leader growth as a result of site and treatment. The ANOVA results show that there is a significant, but complex site x treatment x species 3 way interaction effects.

TABLE 3

Total Percentage Mortality In Reference And Treated Plots

	SPRUCE		PINE	
	Reference	Treated	Reference	Treated
Level	1.5	7.1 (S)	6.1	4.8 (NS)
North	1.5	8.7 (S)	4.5	18.6 (S)
South	12.1	23.0 (S)	16.7	18.4 (NS)

Note: NS = Denotes no significant difference between the pairs of data

S = Significant difference between pairs of data at 95% level

TABLE 4

Percentage mortality (since fall 1982)

	Spruce			Pine		
	Ref.	T1	T2	Ref.	T1	T2
Level	1.5	2.1	1.6	6.1	6.1	2.0
North	0	0	2.4	4.5	10.0	20.9
South	3.3	6.5	28.2	14.1	2.5	21.2

The data in Tables 5 and 6 show the site x treatment interactions for both leader growth and total height. Note that on the reference plots we get the best leader growth and total height on the south slope; whereas on the treated plots we get the test leader growth and height on the level site treatment T1 plots. Treatment T2 plots gives a different trend from the T1 plots. We are not yet able to explain this, but it is not related to the top browning condition described before.

It is also worth noting that total height for both species is not significantly correlated to soil temperture or soil moisture. This has been interpreted as a result of other limiting factors being more predominant at this stage. This observation also throws doubt on the validity of our conclusion from the literature survey.

Whilst I didn't mention in any detail at the beginning our grass seeding experiment, I should mention here that we are finding that there are significant and complex 4-way interactions between site x treatment x species and replicate (grassing treatment). The data in Table 7 shows that the average height of spruce is reduced in each of the grassed plots relative to that of the paired ungrassed replicates. This trend is not apparent with pine on the north T1 and south T2 plots, presumably as a result of other overiding factors.

4. SUMMARY

A. When relatively mild winters prevail we should expect the top browning phenomena to occur. This effect statistically reduces the subsequent leader growth and is directly related to the high mortality in pine.

B. We are observing different mortality rates for spruce and pine and that the spruce isn't doing as well on the treated plots as on the reference plots. The mortality to date under Treatment T2 is almost twice that under Treatment T1.

* * * CELL MEANS * * *

L3 Leader 1983
BY SITE Site
TREAT Treatment
SPECIES Species

TABLE 5

SITE	TREAT 0	1	2
1	3.76 (127)	6.11 (371)	5.61 (374)
2	4.32 (129)	3.74 (238)	4.58 (218)
3	5.74 (113)	5.24 (236)	2.93 (162)

* * * CELL MEANS * * *

H3 Height 1983
BY SITE Site
TREAT Treatment
SPECIES Species

TABLE 6

SITE	TREAT 0	1	2
1	11.05 (127)	15.23 (371)	14.28 (374)
2	11.94 (129)	9.99 (238)	12.26 (218)
3	16.78 (113)	14.83 (236)	9.74 (162)

NOTE: Site 1 = Level
2 = North
3 = South

TREATMENT 0 = Reference
1 = T1 Plots
2 = T2 Plots

TABLE 7

Comparison of average height, grassed and control plots

Site	Soil Treatment	Control plot	Grassed plot
		Spruce	
North	T1	12.45	11.37
"	T2	13.14	12.44
South	T1	13.13	11.49
"	T2	8.56	8.41
		Pine	
North	T1	10.57	20.93
"	T2	12.37	10.29
South	T1	19.88	14.27
"	T2	8.66	12.84

C. There are significant site x treatment x species interactions affecting leader growth and total height. Total height is not correlated to soil temperature and soil moisture at this stage of growth.

REVEGETATION PLANNING TO MEET FORESTRY AND WILDLIFE RECLAMATION OBJECTIVES IN THE GREEN ZONE

J. Bondy, Alberta Forest Service

R. Millson, Fish and Wildlife Division

Introduction

The administration and management of renewable resources in the Green Area (forested) of the province of Alberta is the responsibility of Energy and Natural Resources. In particular, it is responsible for the management of the vegetation resource that supports fish and wildlife habitat, commercial forest operations, recreation, grazing, and the watershed.

For the purposes of this discussion, we will assume that inventories associated with predevelopment planning have accurately described the biophysical environment and the various resources. Based on these inventories and expected post mining conditions (e.g. topography), a reclamation plan is prepared which specifies the types, distribution and species content of the vegetation communities which will be created. It is important to understand that predevelopment planning is the key to the successful reclamation of renewable resources, along with the understanding that it may not be possible to maximize both resources within the same area; e.g., an area cannot be reforested to 100% commercial

timber production and expect that this maximizes the area's wildlife habitat. While it is the responsibility of the operator to prepare the reclamation plan, the use of predevelopment inventories and discussions with the Alberta Forest Service and Fish and Wildlife Divisions prior to the development of the mine will ensure an acceptable reclamation plan.

It is recognized that the replication of the pre-mining vegetation patterns will not occur. It is not practical or desirable to restore predevelopment vegetation cover that will not be compatible with the new reclaimed surface; e.g., the return of muskeg vegetation cover to a reclaimed surface that has been elevated to an upland site during surface mining. Flexibility will be allowed in reclamation planning, keeping in mind that the intent is to return the land to "a site which will support plant and animals life or be otherwise productive or useful to man at least to the degree it was before it was disturbed", and be harmonious to the region in respect to landform, vegetation, and natural drainage systems.

Objectives of Revegetation

The first priority of revegetation in the forested areas is to protect the land surface from erosion. Revegetating the disturbed area will improve water quality and help restore runoff to levels

that existed prior to development. It is recognized that mining will change some of the characteristics of the watershed, resulting in some change in the system's flow regime.

In controlling erosion, plants that will provide a quick, permanent, protecting cover and enrich the soil should be given priority. However, once the ground surface has been stabilized, attention should be given to using woody species to restore the watersheds ability to control water runoff. While specific guidelines are lacking as to what percentage of the watershed basin should be covered by woody species (in particular tree species), current data suggests that water levels being discharged from the basin do not increase significantly until 50% of the tree cover is removed. Applying this to the reclamation of a disturbed watershed basin, it would be expected that a minimum of 50% of the area be revegetated or vegetated with tree and shrub species.

While the maintenance of water quantity and quality is of paramount importance, the establishment of vegetation communities to support other land uses is also very important.

Two of the major land uses associated with the vegetation in the Green Area are those relating to the wildlife and forestry resources. While it is recognized that there are other uses associated with the vegetation (e.g., recreation, grazing), we will deal only with forestry and wildlife habitat in this presentation. To formulate a revegetation plan for these two resources, the following concepts should be considered.

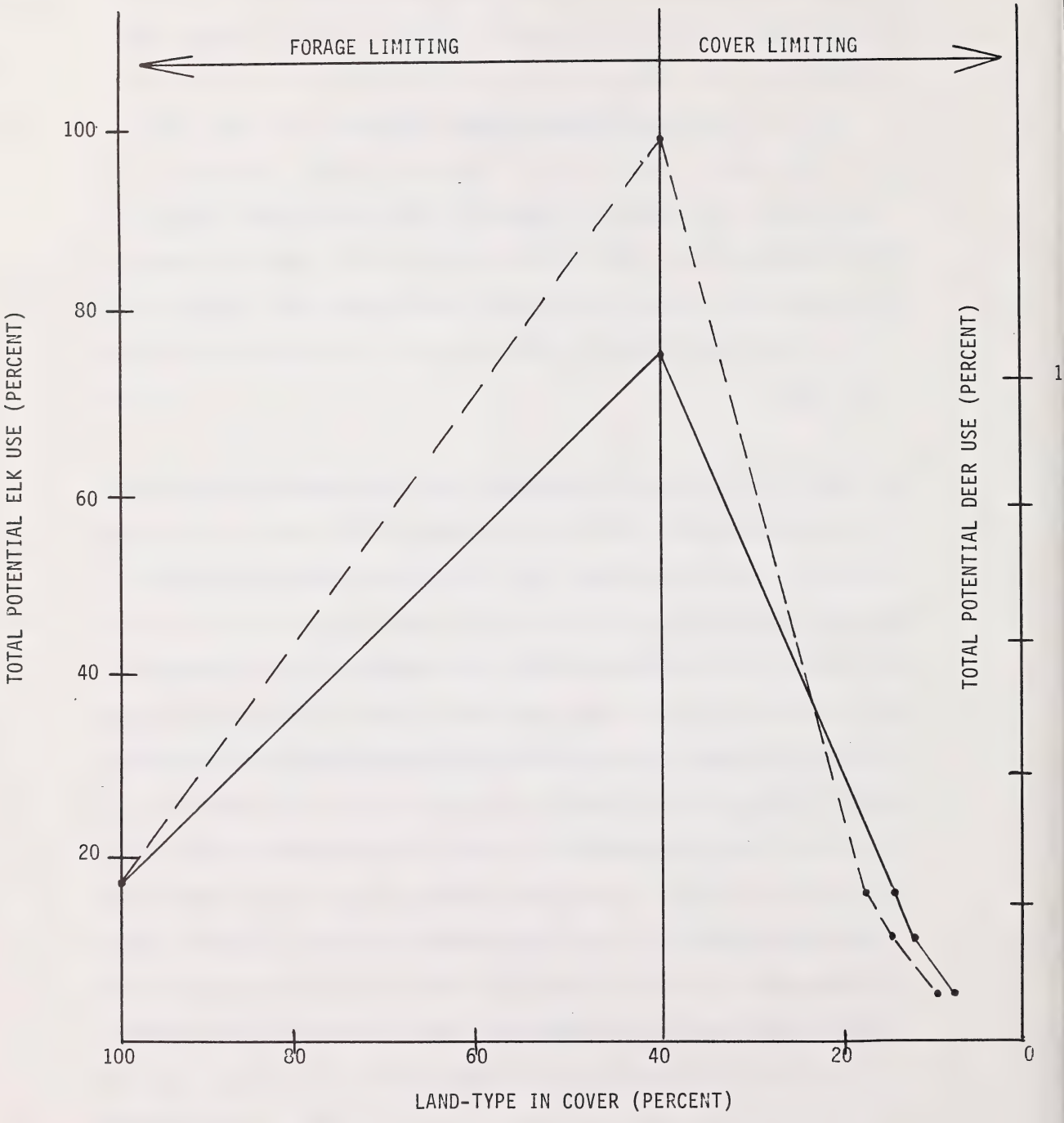
Wildlife Related Vegetation

The discussion about revegetation for wildlife habitat is intended to provide a very brief look at how we approach the creation and evaluation of terrestrial wildlife habitats. We will also present a mechanism for evaluating the quality of habitat created by various revegetation options.

Before discussing the planning of revegetation for wildlife habitat, we wish to describe the concepts of planning and wildlife habitat which form the basis for this discussion. We view planning to be a process in which the planner's goals and objectives for a model. He then organizes his resources into a design or plan which is compared to the model. The plan is then modified and retested against the model until the two are adequately similar to consider the planning process complete. Wildlife habitat is an area which provides for an animal's requirements of food, cover (thermal and escape) and water. These resources must be distributed so as to be available to an animal. The animal must also have a "secure" situation in which to use them. In the mountain and foothill mining situation which we are addressing today, water and thermal cover are usually not a limiting factor. Therefore, we are dealing primarily with food production, escape cover and their distribution.

Whenever you revegetate an area, you create habitat of a certain quality for a collection of species. By modifying the revegetation strategy you can change the quality of the habitat and the list of species for which it is appropriate. Systems exist which permit the simultaneous evaluation of changing habitat parameters on large numbers of species. However, for the purposes which we are discussing today, they are just too much work. We would suggest selecting one or two animal species which you will target for. This process will benefit other species with similar habitat requirements.

The lack of an organized plan of goals and objectives for habitat creation has been a major problem to planners. This problem was addressed by the U.S. Forest Service in their attempts to integrate wildlife habitat consideration into the management of the forests of the Blues Mountains (Jack Ward Thomas, 1979). The graph that I am showing is for a closed canopy fir forest and predicts how the deer and elk populations will respond to changes in the ratio of open to forest habitat types. This type of information does not plan your revegetation program but does tell you what the impact of your various options will be on wildlife habitat for various species and assists with developing of planning objectives. The Alberta Forest Service, Fish and Wildlife Division, and St. Regis are currently implementing a forest management planning model based on the Jack Ward Thomas method for the St. Regis


FORAGE LIMITING
COVER LIMITING
100
80
60
40
20
TOTAL POTENTIAL ELK USE (PERCENT)
TOTAL POTENTIAL DEER USE (PERCENT)
100
80
60
40
20
0
LAND-TYPE IN COVER (PERCENT)

Forest Management Area. This will produce graphs similar to the one shown for Alberta vegetation communities and our wildlife species. This model is scheduled to be operational by the end of this year and its preparation is currently on schedule. The identification of individual plant communities is based upon the requirements of the target species.

When you have decided what the ratio of vegetation types will be, there are several other considerations: 1) dispersion of communities and, 2) species selection. The dispersion of communities has several impacts on the value of an area as wildlife habitat. The spatial distribution of the vegetation communities can be modified to maximize edge and the benefits to wildlife. Also, it has been documented that deer and elk use of openings is heaviest around the edge with little use of the center of large clearings. By modifying the spatial distribution of plant commmunities, clearings can be sized to optimize their use. Another consideration in optimizing the use of clearings by some wildlife species (such as deer and elk) is to manage the "line-of-sight" which is usually limited by the topography or vegetation. It is recommended that "line-of-sight" be less than 360 m to optimize the use of deer and elk habitat. The literature recommends that cover blocks for elk and deer be between 183 and 366 meters across. There are a number of other considerations in planning the distribution of vegetation types such as the importance of riparian areas diversity and aspect.

A final consideration in creation of wildlife habitat is the selection of plant species. Much has been written about the feeding habits of the major wildlife species. This information, when combined with the site-hardiness data about the plant species, permits the selection of species which are suitable for the site and of value to wildlife.

Forestry Related Vegetation

The extent and composition of forest cover for revegetation is dependent upon the predevelopment inventory and its incorporation into the approved reclamation plan. The inventory must take into account any land use activity that is being made of the forest environment. Generally, from a forester's perspective, forests can be divided into two areas; forests for commercial timber production and forests for non-commercial uses such as wildlife habitat, watershed protection, and recreation.

The determination of land areas that will be required to return a commercial forest is dependent on the amount of land being disturbed that is considered to be productive by the Alberta Forest Service. In the broadest sense, land which is stocked with commercial tree species and is capable of producing 50 + $m^{3/ha}$ gross timber volume at the end of a 120 year rotation period is considered to be productive. This would mean that, if an area to be disturbed has 2000 hectares of productive forest land, the

objective of the Alberta Forest Service is to see that 2000 hectares of reclaimed land will be reforested to acceptable species and stocking rates. The operator should ensure that lands being reclaimed to productive forest be placed together to make them worthwhile for harvesting and accessible for timber removal. At the present time, the determination of productive forest land can be accomplished by the use of the "Alberta Forest Service Phase III Inventory Specifications" document, along with an adequate soil survey that will assist in defining the limits of productivity for the various timber sites.

Information of acceptable stocking levels and species is found in Section 137 of the Timber Management Regulations. While these regulations apply to timber harvesting operations, they provide an excellent guidelines for mine reclamation.

"137. In order for any area to be classified as reforested in accordance with the required standard

(a) 40 percent of the milacres it includes must contain an established seedling tree,

(b) three-quarters or more of the established seedling trees must be spruce, pine, or douglas fir; and the other one-quarter or less must be balsam, fir, birch, or poplar seedling trees,

(c) it cannot contain any areas larger than 10 acres in extent, which do not in themselves meet the required stocking standard, and

(d) identifiable areas larger than three acres, which in themselves do not meet the required stocking standard, must not in the aggregate exceed 20 percent of the total area to be classified."

Generally, an operator will be looking at approximately 1000 seedlings per hectare of acceptable species to meet the minimum stocking level. However, the operator must allow for mortality, which would mean planting more than the 1000 minimal stocking figure. The Alberta Forest Service, as part of their reforestation program, plants approximately 1250 seedlings per hectare for average sites and up to 1700 seedlings for harsh sites, but the operators will have to find their own mortality figures by trial and error if research data is not available for their particular area.

In addition to the stocking standard, the Alberta Forest Service is presently looking into growth performance standards that will have to be met prior to a Reclamation Certificate being given. To this end, the Alberta Forest Service will be participating in the Mountain/Foothills Research Study that will examine growth performance rates that would be expected of commercial tree species used in reclamation. However, until this study is completed,

the operator will be required to meet the same stocking level within a certain period of time. This would mean that a minimal of 7 to 10 years would have to be allowed from the time of initial planting, to evaluate if successful reforestation has taken place.

The identification of lands that are considered to be non-productive (as defined by Phase III) because of low productivity, inaccessibility, or having more value for wildlife habitat, watershed protection, or recreation, must occur early in predevelopment inventories and be incorporated into the approved reclamation plan. It is important that these two area (productive versus non-productive) be identified in the reclamation plan, because different standards will be applied in the certification process, depending on the land use identified and approved.

Integration of Wildlife and Forestry Objectives

There is a general perception that combining forestry and wildlife habitat land use objectives on the same piece of ground is an impossible feat. We don't feel that this is an accurate assessment, but it is understandble. We each have our mandates and they are occasionally in conflict. When either agency is approach individually, we have traditionally expressed our opinions and desires but, as Energy and Natural Resources representatives, it would be undesirable for us to take opposing sides in such

a situation. Review by our respective agencies usually results in several acceptable compromises. What we wish to do here is describe some of the components of these compromises so that you may be able to use them in your planning.

First, the Fish and Wildlife Division and Alberta Forest Service are both agencies of the Provincial Government. The Fish and Wildlife Division recognizes that many resources, including the forestry resources, are very important to the province in terms of employment, revenues, recreation, etc. The Forest Service recognizes that there are many resources, including the wildlife resource, that are very important for the same reasons. There are very few sites in the province which have capabilities for both wildlife and forestry resources where one resource exceeds the other in importance to the extent that one is excluded from consideration.

We have identified three levels at which integration of the two land uses is necessary to produce the desired results from the vegetation plan. These are the identification of:

1. desired end land uses

2. desired mixture of vegetation communities

3. species selection for communities.

It must be remembered that at each stage, the conclusions must be appropriate for the site. Each level will be discussed individually.

1. End Land Use

The first priority in the revegetation plan is watershed protection. It is also necessary to define, at least qualitatively, the relative importance which will be granted to timber vs. wildlife production. This will be based on the predevelopment inventory information and limitations imposed by the postdevelopment landscape. The decision will also be influenced by the inherent value of the area and projected demand. If the identified land use priorities differ greatly from the pre-mining situation, the changes should be justifiable.

2. The Desired Mixture of Communities

The desired mixture of communities must first meet the water resource requirement of 50% woody vegetation in the basin. Beyond this, the selection should be designed to meet the land use objectives described in the preceding section. The timber production component can be evaluated in terms of hectares planted to acceptable forest species of commercial value and at the desired density. The wildlife production component can be evaluated using the response curves for the appropriate species and vegetation types, and information regarding the requirements of the chosen target species.

The mixture and distribution of community types selected must be appropriate for the site conditions. Some communities are suited to certain sites and this must be a major consideration in their placement. The arrangement of communities should also maximize the vegetation values to wildlife populations and the forest industry. Commercially stocked forest communities should be located in an area in which they are accessible and which is favourable to their growth. It should also be remembered that these commercial forests provide thermal and escape cover and should be intermixed with other vegetation types to optimize

their benefits to wildlife. The remaining plant communities should be distributed to maximize their usefulness to wildlife.

3. Species Selection for Communities

Species selection can be based on many information sources. These include other reclamation endeavours in the area, a companies research program, the knowledge of local resource experts (e.g. Alberta Forest Service and Fish and Wildlife staff), the information acquired in the inventory program and the published literature. Efforts should be made to maximize the benefits of vegetation types through proper species selection. For example, in an area where a fast growing, erosion control species is required, a species should be selected which also has a good soil building characteristics. In an area reclaimed for a commercial forest, an understory may be planted which will permit significant forage or browse production until the forest species shade it out.

The above considerations include some rather simplistic suggestions to integrate the forestry and wildlife habitat interests in reclamation planning . We are convinced that a little effort will produce a solution acceptable to the Fish and Wildlife Division and Alberta Forest Service.

WILDLIFE END USES IN RECLAMATION:
CONCEPTS AND OPPORTUNITIES

By

Jeffrey E. Green,

LGL Ltd., Edmonton

and

Keith S. Yonge,

Canadian Wildlife Service, Edmonton

A paper presented to the

Reclamation Research Technical Advisory Committee

May 1, 1984

Edmonton, Alberta

I. INTRODUCTION

The Alberta Land Surface Conservation and Reclamation Act recognizes four major land uses as end use objectives for reclaimed land: forestry, agriculture, recreation and wildlife. However, until the past decade, only forestry and agriculture end uses were given much consideration for reclamation in Alberta, and Reclamation Standards for wildlife and recreation have not yet been developed. Although forestry has been the predominant end use objective for reclamation sites within the Mountain and Foothills biomes (Marshall 1983), it has become increasingly apparent that wildlife habitat offers a viable alternative end use for reclamation, particularly within the green zone of Alberta (Markum 1980; Hardy and Associates Ltd. 1982; Millson and Bondy 1984).

A number of factors have contributed to the recent recognition of the potential of reclamation for wildlife:

1. an extensive data base of revegetation techniques has gradually accumulated. This data base includes detailed information on propagation, planting and species suitability of grasses, legumes, herbs, shrubs and trees. Our increasing ability to construct plant communities now provides the opportunity to control the development of wildlife habitat;

2. because of recent increases in public and government recognition of the economic, commercial and aesthetic importance of wildlife and wildlife-associated activities (Filion et al. 1983), there is

increasing public and government support for reclamation to wildlife habitat;

3. many aspects of reclamation of wildlife habitat can be readily integrated with other end uses (Millson and Bondy 1984), and development of wildlife habitat can often enhance, rather than conflict with, the results of reclamation for forestry;

4. because of the diverse habitat requirements of wildlife, reclamation of wildlife habitat can provide operators with a high degree of flexibility in the reclamation plan. This can be particularly helpful in achieving successful reclamation on areas where more conventional reclamation methods may be impractical; and,

5. because some methods for reclamation of wildlife habitat require only minimal use of equipment and manpower and low materials costs, reclamation of wildlife habitat often may be the most practical and cost effective end use for specific areas.

Wildlife end uses in reclamation are usually compatible with forestry objectives and are readily integrated with forestry end uses (Barr Engineering Co. and Borovsky 1980; Dickson and Vance 1981; Proctor et al. 1983; Millson and Bondy 1984). In some cases, however, wildlife habitat may be the only practical alternative for a reclamation site and thus may provide reclamation planners with opportunities to deal with troublesome sites. For example, wildlife habitat may be the most appropriate objective for sites such as steep slopes, areas with unproductive soils, extreme microclimates, and rock

outcrops and headwalls, many of which are notoriously difficult to stabilize and revegetate. Once these areas have been revegetated, it is unlikely that timber harvest (a forestry end use) or cultivation (an agricultural end use) would be desirable or practical. In these instances, wildlife end uses would provide operators with a practical reclamation alternative. Other sites, such as borrow pits and open mine pits, can often be reclaimed with only slight modification to benefit wildlife, whereas extensive site development may be necessary to meet criteria for forestry or agricultural production. Small areas, where large scale forestry or agricultural end uses are impractical, are also ideal for reclamation to wildlife habitat. Furthermore, disturbed areas of high traditional importance to wildlife, such as aquatic sites, bottom lands, riparian areas or special use areas for wildlife (e.g., wintering areas for elk), should usually be reclaimed for wildlife, regardless of the feasibility of other end uses.

Prior to the 1970's, wildlife managers and reclamation planners rarely took advantage of these opportunities. The major reason for this was that reclamation standards and regulations in Alberta have traditionally stressed forestry and agricultural end uses. Hence, reclamation planners were not fully aware of the option of reclamation of wildlife habitat, nor willing to depart from the traditionally accepted end uses. Furthermore, the wildlife habitat option, if considered at all, was generally considered late in operational planning by which time the manpower, equipment and material requirements were often excessive (Harrison 1984). The cost of reclamation to wildlife habitat can be high, when done as an afterthought.

Combined, the above factors have resulted in and still contribute to an

under utilization of the wildlife end use in reclamation. Few reclamation plans consider reclamation or enhancement of wildlife habitat as an integral component of the reclamation effort. And although wildlife concerns are frequently identified in the pre-development environmental impact assessments, few site development plans incorporate wildlife end uses as primary or secondary land use objectives for reclamation.

The growing data base of reclamation research and experience (Utah State University 1978; Elliott and McKendrick 1982; Harrison 1984; Millson and Bondy 1984) provides ample evidence that the technology is now available and that the climate is right for wider acceptance of wildlife end uses as alternative goals in reclamation.

II. CONCEPTUAL APPROACHES TO RECLAMATION OF WILDLIFE HABITAT

When attempting to reclaim or enhance wildlife habitats in a reclamation site, there are a number of factors that should be considered during the planning and implementation stages of the reclamation plan. Prior to development there is a need to obtain adequate pre-disturbance information on wildlife uses and habitats in and adjacent to the proposed site. Pre-disturbance information on the abundance, distribution, and diversity of wildlife, on the special wildlife uses of an area, on the abundance and distribution of vegetation, on the interspersion of habitat types, and on water availability and topography can provide a framework for development and reclamation plans (Barr Engineering Co. and Borovsky 1980; Dickson and Vance 1981; Proctor et al. 1983). For example, information on the abundance and diversity of wildlife can be used to determine the "target" wildlife species for the reclamation effort. Similarly, information on vegetation and habitat interspersion can be used to select appropriate species for reclamation and to design the landscape plan for the reclamation site.

Successful enhancement of disturbed areas for wildlife must provide the basic requirements for food, water, cover, and range (Dickson and Vance 1981; Canadian Wildlife Service 1981; Proctor et al. 1983). Reclamation for wildlife should consider factors such as plant diversity, species composition and interspersion, habitat dispersion and edge habitats, water regime, proximity to water, and topography. In some cases, isolation from human disturbance may also be an important consideration. Generally, an area with a diversity of habitats is capable of supporting a greater variety of wildlife than areas with a limited number of plant communities. Diversity is the key

to successful reclamation for wildlife, and reclamation programs for wildlife habitat should maximize the diversity of habitat, topography and vegetation.

The primary objective of reclamation for wildlife habitat should be to re-establish a diversity of self-sustaining plant communities that will benefit a variety of wildlife. Once these communities are established, natural ecological processes should be allowed to direct successional trends in the plant community.

Wildlife ecology and habitat use usually involves a complex array of interspecific and intraspecific relationships, thus methodologies for enhancement of wildlife habitat can also be complex. To simplify the objective of establishing a diversity of self-sustaining plant communities, we believe that reclamation of wildlife habitat should be directed initially towards the rapid establishment of early seral plant communities that are of benefit, in the short term, to wildlife species adapted to early seral communities. There are several advantages to this approach:

1. plant associations in early seral communities are generally simpler than in mature or climax communities, and thus reclamation requirements for re-establishing these communities are less complex;

2. the establishment of early seral communities is a realistic and attainable goal for reclamation, and thus, within a relatively short term, provides an opportunity to evaluate the wildlife enhancement program;

3. early successional wildlife species are most likely to be attracted to reclamation areas, thus by encourarging recolonization by those species, rather than species adapted to more mature plant communities, re-establishment of the wildlife communities will be faster and more complete;

4. the development of early seral plant communities accelerates plant succession towards a more mature, stable plant community and thus indirectly benefits those wildlife species that depend on these habitats, ultimately resulting in a more stable plant and wildlife community;

5. because results of the reclamation program, evident through wildlife use, will be visible in a relatively short period (within 5 to 15 years), the company and its employees receive positive reinforcement for their efforts through visible success in enhancing wildlife habitat;

6. because results may be realized in a relatively short period, there can be a strong public relations benefit to the company through reclamation of early successional communities for wildlife.

Although the major focus of a wildlife enhancement program should be the establishment of early seral communities, methods which promote rapid succession towards mature plant communities are also available and can be utilized where required for specific sites.

III. THE CONCEPT OF KEY WILDLIFE SPECIES IN RECLAMATION

A large number of wildlife species may be present or potentially utilize reclamation sites and edge habitats around a site (Verts 1959; Voight and Glenn-Lewin 1979; Whitmore 1980; Brenner et al. 1980). To design the reclamation of a site for the direct benefit of all of these species would be complex, inefficient and costly. In order to provide a clear conceptual framework for reclamation of wildlife habitat, we suggest that the reclamation plan be aimed at a small number of target wildlife species. By improving habitat for target species, much of the wildlife community would be enhanced, since the complex of wildlife species within a given plant community generally have similar habitat requirements. Thus reclamation efforts aimed specifically at a small number of key species is likely to benefit the majority of the wildlife species that may potentially occupy the site.

Because of the pivotal role of key species in designing and implementing a reclamation plan for wildlife, they must be selected with care. Important criteria for selection of key species are:

1. they should be common to the area, both prior to and during site operation;

2. they should be adapted to or capable of using early successional habitats;

3. they should be ecological generalists, with habitat requirements similar to other local wildlife species.

In the foothills for example, wildlife species such as blue grouse (Dendragapus obscuras), mallard (Anas platyrhynchos), snowshoe hare (Lepus americanus), elk (Cervus elaphus) and moose (Alces alces) would be suitable target species, whereas species such as mountain caribou (Rangifer tarandus), collared pika (Ochotona princeps) or spruce grouse (Canachites canadensis) would be less suitable.

For most areas of Alberta, we recommend selecting at least one target species from three key wildlife groups -- an ungulate, an upland game bird and a terrestrial furbearer. If waterbodies or watercourses are an important feature on the site, or if features such as pits or waste water ponds are prominent in the development, a waterbird and possibly an aquatic furbearer should also be selected.

IV. TECHNIQUES FOR RECLAMATION OF WILDLIFE HABITAT: AN EXAMPLE

To illustrate some of the general techniques that may be used for reclamation of wildlife habitat, and to illustrate methods for integrating some of these techniques, a highly simplified and hypothetical example of a proposed mine development in the foothills biome of Alberta is provided in Figure 1. Baseline studies of this mine site prior to development indicated several prominent wildlife features of the site (Figure 1). These included a permanent stream along the valley bottom that separated the proposed mine site from the plant area, a small oxbow lake and associated marsh, an open meadow community along the southwest slope of the valley (in the vicinity of the proposed open pit mine), and an established game trail through the proposed development area (with one branch of the trail following the stream to the marsh area and the other branch running southwest towards the next valley). Prevailing winds in the area are from the southeast.

i) Reclamation Without Wildlife End Uses

A mine site plan without wildlife values might resemble the layout shown in Figure 2. During the initial development of a site, much of the native forest cover was cleared to aid surveying of the site, movement of equipment, and construction. Loss of the native plant cover restricts wildlife movement through a site and reduces use of the area by some species of birds and mammals. Figure 2 shows a large area of forest has been cleared for the plant and camp sites, haul roads and overburden stockpile. The pit mine has replaced the open meadow community and some of the surrounding forest cover, and the overburden pile has covered the oxbow lake and associated marsh. A

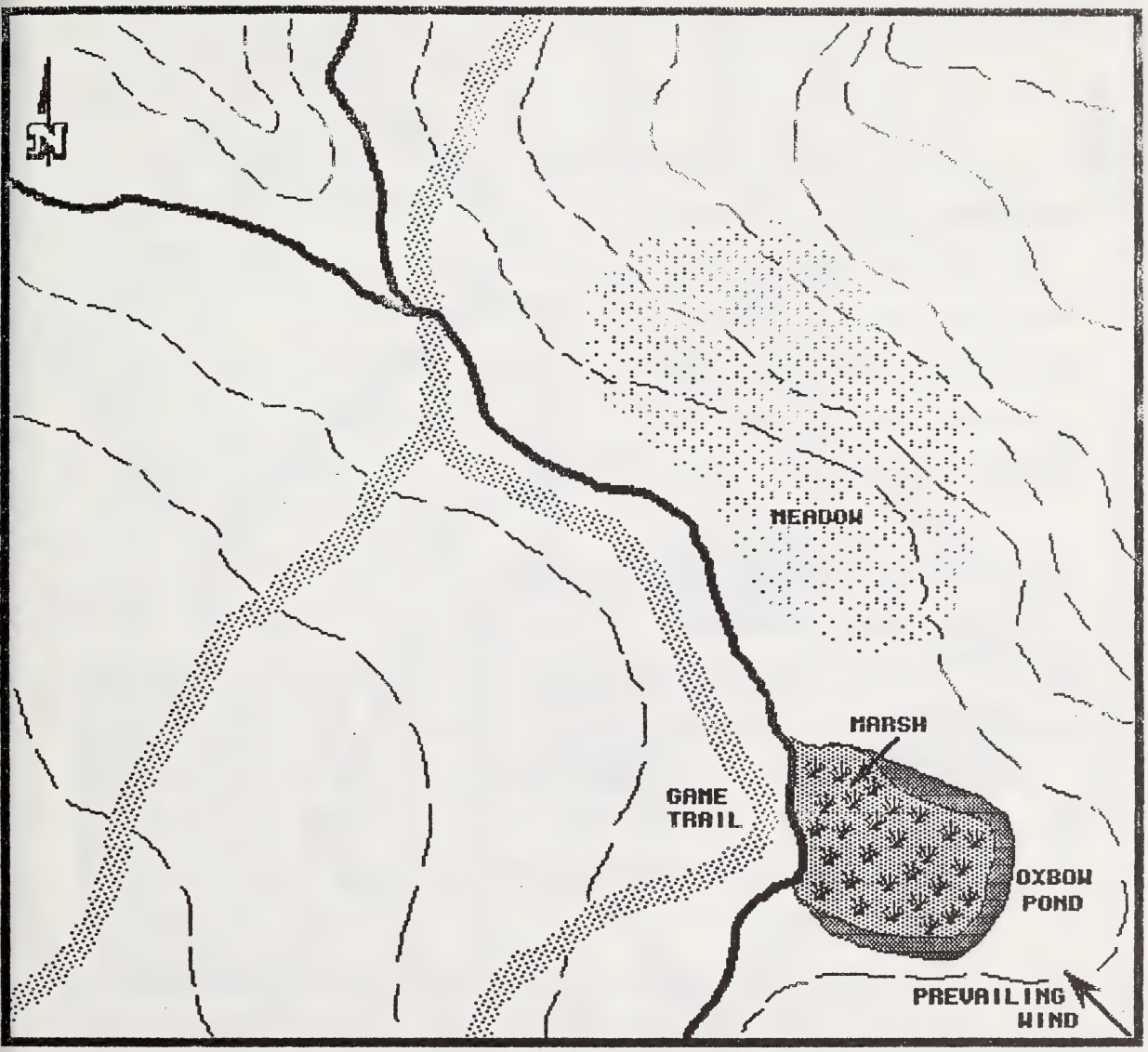


Figure 1. Example of a hypothetical mine site prior to development.

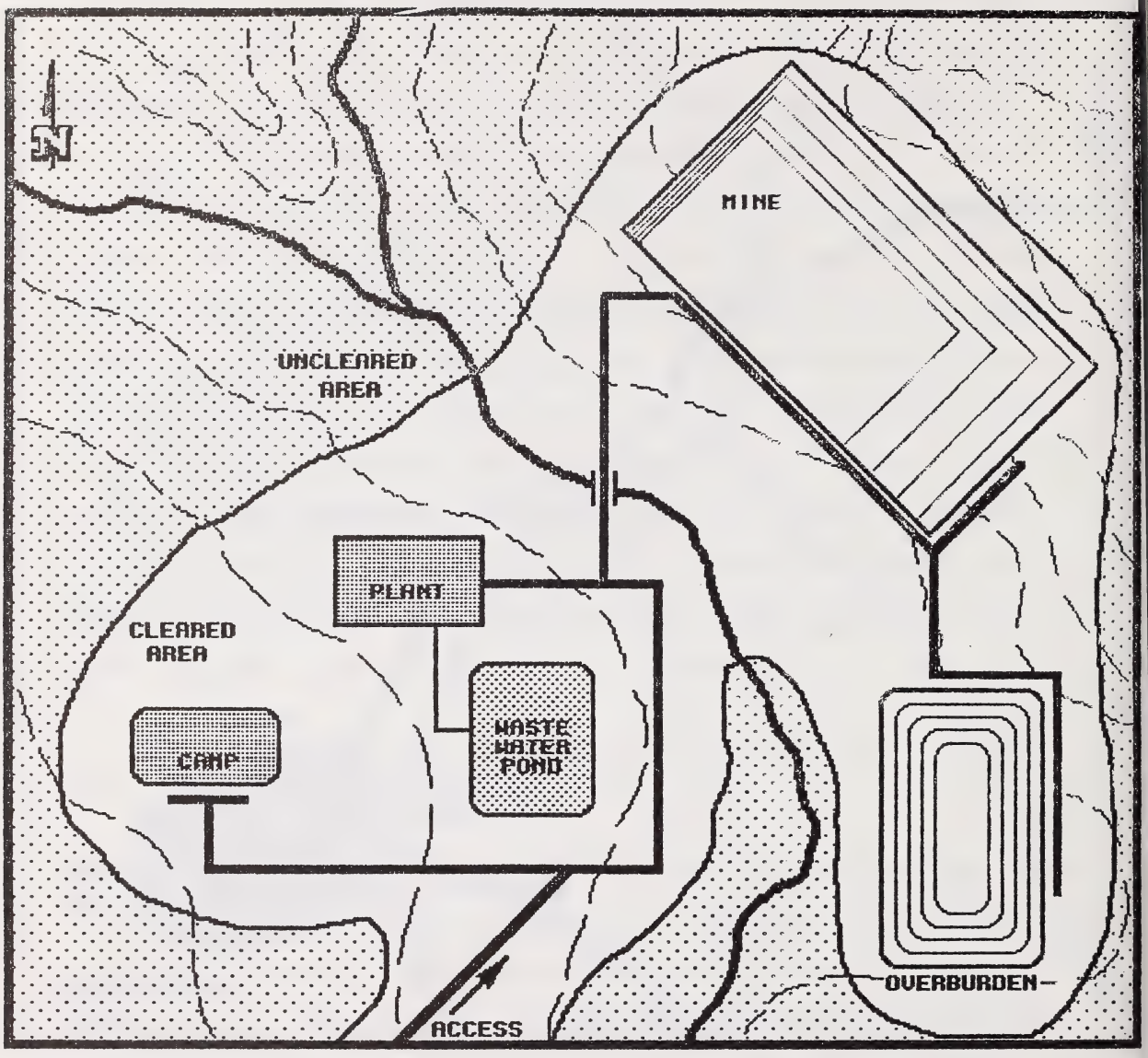


Figure 2. Example of a hypothetical mine site plan which does not allow for wildlife values.

steep headwall is also present along the northwest face of the mine pit. The plant, waste water pond and camp occupy most of the gentle west slope of the valley.

In the event that wildlife end uses were not incorporated into the reclamation plan for the site, a simplified reclamation plan for the area might resemble Figure 3. The mine site has been recontoured to reduce the slope angle and to minimize erosion. Following recontouring and replacement of the top soil, much of the mine pit and the cleared area might be reseeded with a mixture of agronomic grasses and legumes. Fertilizer ammendments might be applied at regular intervals for several years. Tree plantings included in the plan would most likely be uniformly spaced monotypic plantings of commercial conifers such as lodgepole pine (Pinus contorta) or balsam fir (Abies amabilia). Such tree plantings may discourage use by wildlife, particularly those species requiring more diverse plant communities. Uniform planting regimes may also attract browsing wildlife species, such as snowshoe hare (Lepus americanus) or deer (Odocoileus spp.), and allow them to more effectively search out and consume seedlings (Proctor et al. 1983), resulting in widespread and costly impact on the reclamation effort.

Waste water ponds, if non-toxic, are often abandoned without modification. Such ponds typically have steep sidewalls and flat bottoms which limit the development of aquatic biota and restrict use of the pond by wildlife. Steep sidewalls and water depths greater than 2.0 m restrict the development of aquatic emergent vegetation, which in turn will limit the amount of aquatic plant food for fauna and the amount of nesting cover available to wildfowl (Olson 1981).

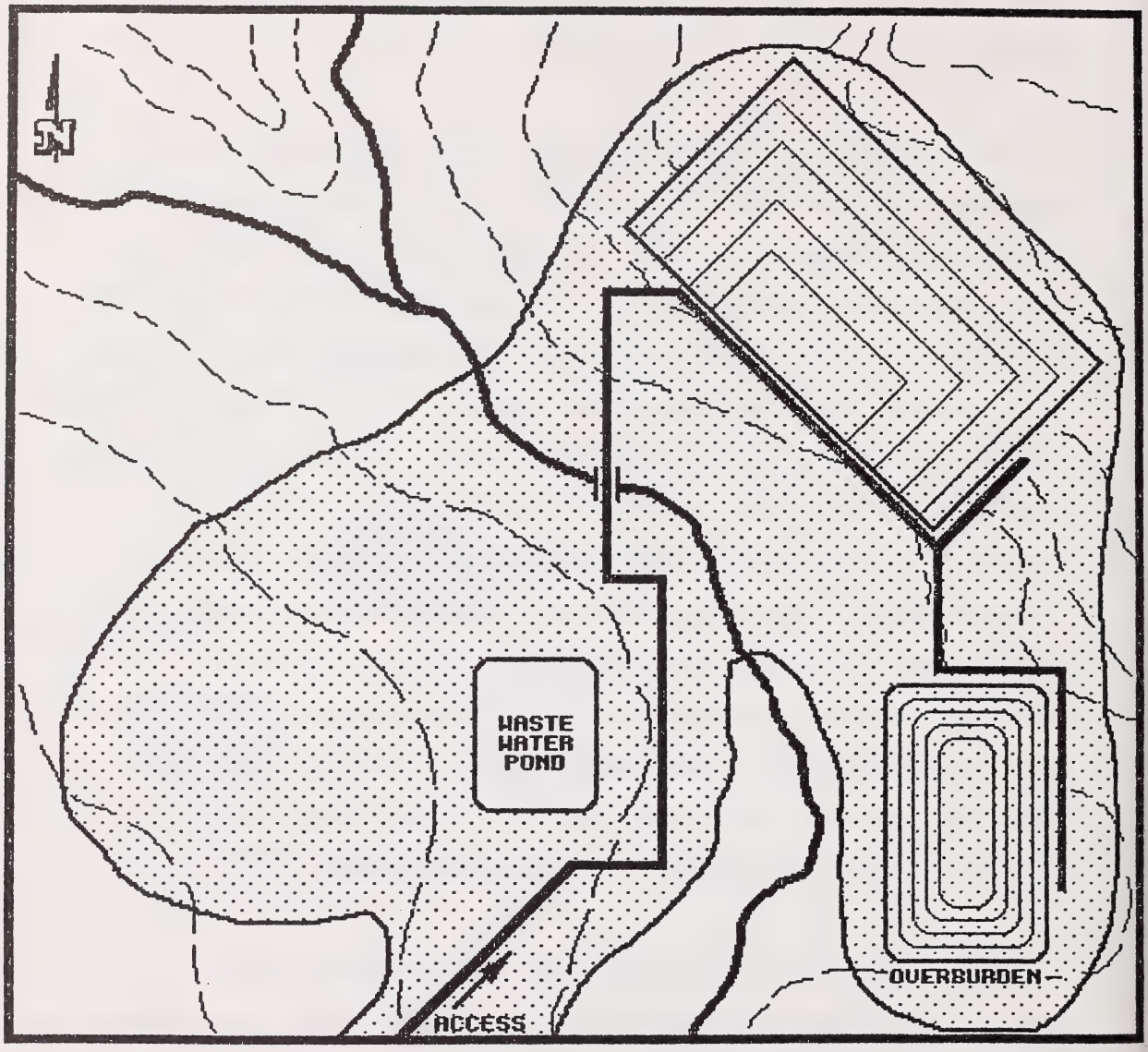


Figure 3. Example of a hypothetical site reclamation plan which does not incorporate specific wildlife end uses.

ii. Reclamation with Wildlife End Uses

On designing a reclamation plan for this hypothetical mine that incorporates a wildlife end use, a number of techniques could be used to improve the value of the site for wildlife. Several features of the existing site offer good opportunities for enhancing wildlife habitat: the large open area previously occupied by the plant and camp, the waste water pond, the open mine pit, and the overburden pile (Figure 2).

The open visual expanse of the plant/camp area would probably limit the use of the area by wildlife because of the exposure of animals to predators, human disturbance and climatic extremes. Figure 4 provides a simplified example of how the site might be reclaimed to encourage wildlife use. In order to break the visual expanse of the area and to provide shelter for wildlife, clumped plantings of trees and shrubs could be established throughout the site. Until shrubs and trees become established on the site, artificial cover such as rock piles or brush piles can be placed to provide cover for small mammals and songbirds (Dickson and Vance 1981; Hardy Associates Ltd. 1982; Proctor et al. 1983). Clumps might consist of mixed shrub plantings or mixed plantings of trees and shrubs. Use of irregular shaped clumps, random spacing, and mixtures of tree and shrub species would increase the amount and diversity of edge habitats which are important to most species of wildlife (Dickson and Vance 1981; Proctor et al. 1983). Each clump should consist of several species of shrubs and/or trees that include preferred and unpalatable browse species (Hardy Associates Ltd. 1982) for the key herbivores selected for the site. Mixed groupings of trees and shrubs might have a planting pattern similar to that shown in Figure 5, with

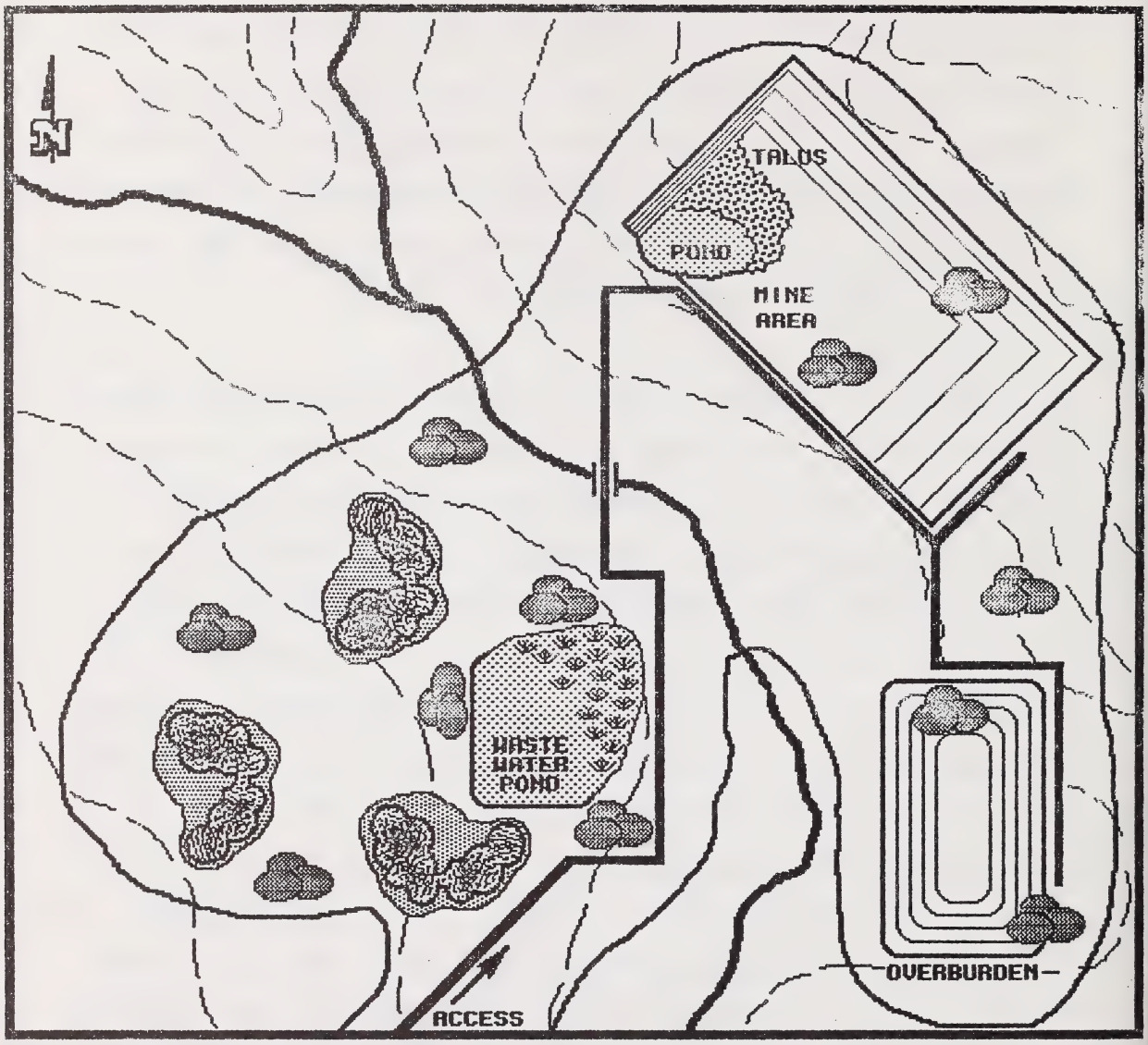


Figure 4. Example of a hypothetical mine reclamation plan which incorporates a wildlife end use. A highly simplified pattern of clumped vegetation is shown.

Figure 5. Cross-section of a possible planting configuration for shrub and tree clumps in reclamation areas (from Canadian Wildlife Service 1981).

coniferous species occupying the centre area of the clump. Deciduous trees, tall shrubs and low shrubs would surround the central coniferous trees (Canadian Wildlife Service 1981; Vogel 1981). Preferred browse shrubs and herbaceous species could be planted throughout the clump.

Spacing between the shrub and tree clumps should be adjusted for the key species selected for the site. The distance between the clumps should not exceed the distance the key species will normally venture from the forest edge. Locations of the tree and shrub clumps should accomodate movement patterns of wildlife through the site (Dickson and Vance 1981; Knott and Samuel 1982). In our hypothetical example (Figure 4), groupings have been spaced to eventually provide some cover in the vicinity of the former game trail. Ground vegetation between the shrub/tree clumps should include native species or permit the invasion of native species from adjacent areas. Ground cover mixes should include species that are both palatable and unpalatable to the key species.

Providing that waste water ponds are non-toxic, they can often be modified to improve greatly their value to wildlife (Giron 1981; Olson 1981; Rikard et al. 1981; Hardy Associates Ltd. 1982; Proctor et al. 1983). Steep side walls, common to many industrial ponds, prevent access for many species of wildlife and may limit growth of emergent aquatic vegetation. If the sidewalls of the pond were graded to a gentle slope, and if more extensive areas of shallow water were created, aquatic vegetation could establish and eventually wildlife use of the pond would increase. Slopes of less than 1:5 and shallows of less than 1.5 metres are recommended (Canadian Wildlife Service 1981). Extensive shallow areas would permit a rapid recolonization by

emergents such as cattails, reeds and bulrushes. Transplants of emergent vegetation or seeding of aquatic plants would promote a more rapid establishment of these plants (Childress and Eng 1979). Irregular bottom contours in the pond also would provide a diversity of water depths that could be used by a greater number of wildlife species (Canadian Wildlife Service 1981). At least a portion of the pond should be deeper than 1.5 metres to prevent freezing to the bottom during winter.

At the completion of a pit mine operation, the pit generally consists of one or several steep headwalls, and various slopes and terraces. If the headwall is stable, some measures can be implemented to improve its value to nesting birds. Ledges on the headwall may provide nesting sites for some raptors, and serve as escape terrain for some mammals. If waste rock is present at the base of the slope, it can be used to create talus habitat for mammals such as marmots (Marmota spp.) or pikas (Ochotona spp.)(Proctor et al. 1983). Addition of soil to some parts of the talus would provide areas for colonization by plants which, in turn, could serve as a food source for these mammals. If a pit is present near the base of the headwall, it could be left as a pond (or enhanced using some of the principles described above for the waste water pond). A pond and its associated wetland plant communities near the headwall would further improve habitat for raptors by attracting prey species such as waterbirds and small mammals near the nesting site (Mumford and Bramble 1969; Sly 1976; Van Waggoner 1978; Hansen and Warnock 1979).

In the remainder of the mine pit, the slopes could be recountoured to provide a variety of slopes and aspects which, in turn, provide a diversity of vegetation communities for wildlife. In some cases only minor recontouring of

terraces or slopes may be necessary to make the area suitable for wildlife, thereby reducing materials handling costs. For example, a moderately steep, south-facing slope planted with grasses, forbes and low shrubs might eventually provide suitable late winter range for ungulates (Hurst and Warren 1981). Assuming that top soils are replaced over the mineral soils, revegetation of the mine pit area could incorporate many of the principles described earlier for the camp/plant area. In this simplified example, the mine area was formerly an open grass meadow (Figure 1) and thus it would be preferable to revegetate the area with native grasses and forbes. Small areas of shrubs and trees could be used to eventually provide cover for wildlife.

Reclamation of the overburden area could involve some of the general techniques described for the plant/camp area and the mine pit. Parts of the overburden area could be recontoured to provide greater topographic diversity (e.g., slope, aspect, and terrain). Revegetation could include planting of shrub and tree clumps, interspersed with areas of grass/forbe ground cover. In this example (Figure 4), shrub and tree groupings were located between the overburden area and the mine pit to eventually promote movements of wildlife between the two areas and to provide protective cover.

iii. Incorporating Wildlife Values in the Site Plan

If a wildlife end use is to be the primary land use objective for the reclaimed area, wildlife values ideally should be considered in the site plan, prior to the actual development of the site and the formulation of the reclamation plan (Proctor et al. 1983). Integration of wildlife uses at this stage of the development allows some areas of the site, particularly those

features that involve movements of large amounts of materials (e.g., overburden piles), to be designed for wildlife with little or no extra cost to the operation. Figure 6 illustrates some of the general techniques.

During the intitial preparation of the site for the development, wildlife use of the area throughout the project life and following reclamation could be improved by minimizing the amount of natural forest and shrub cover that is cleared (Proctor et al. 1983). For example, forested strips (30 - 100 m wide) can be left along water courses to provide a movement corridor for wildlife, to preserve riparian habitats (of high value to a number of species of wildlife), and to limit erosion of soils and eventual sedimentation of the stream (Proctor et al. 1983). Similarly, strips of forest cover could be used to screen haul roads, access roads, and mine activity areas. Maintenance of natural cover in close proximity to the potential reclamation areas will promote wildlife use of the reclamation areas, particularly along the forest edge. The close proximity of natural cover to the reclamation areas also will encourage invasion of native plant species from the forest community.

Preplanning for wildlife end uses in reclamation also will allow material storage areas such as the overburden area to be modified for wildlife use (Proctor et al. 1983). For example, the overburden area in our example could be constructed so as to provide a variety of slopes and aspects, and in turn a variety of vegetation communities (Figure 6). The overburden area also could be oriented to provide shelter from prevailing winds, to provide a large southern exposure for creation of late winter ungulate range, and to encourage microhabitat diversity on leaward slopes.

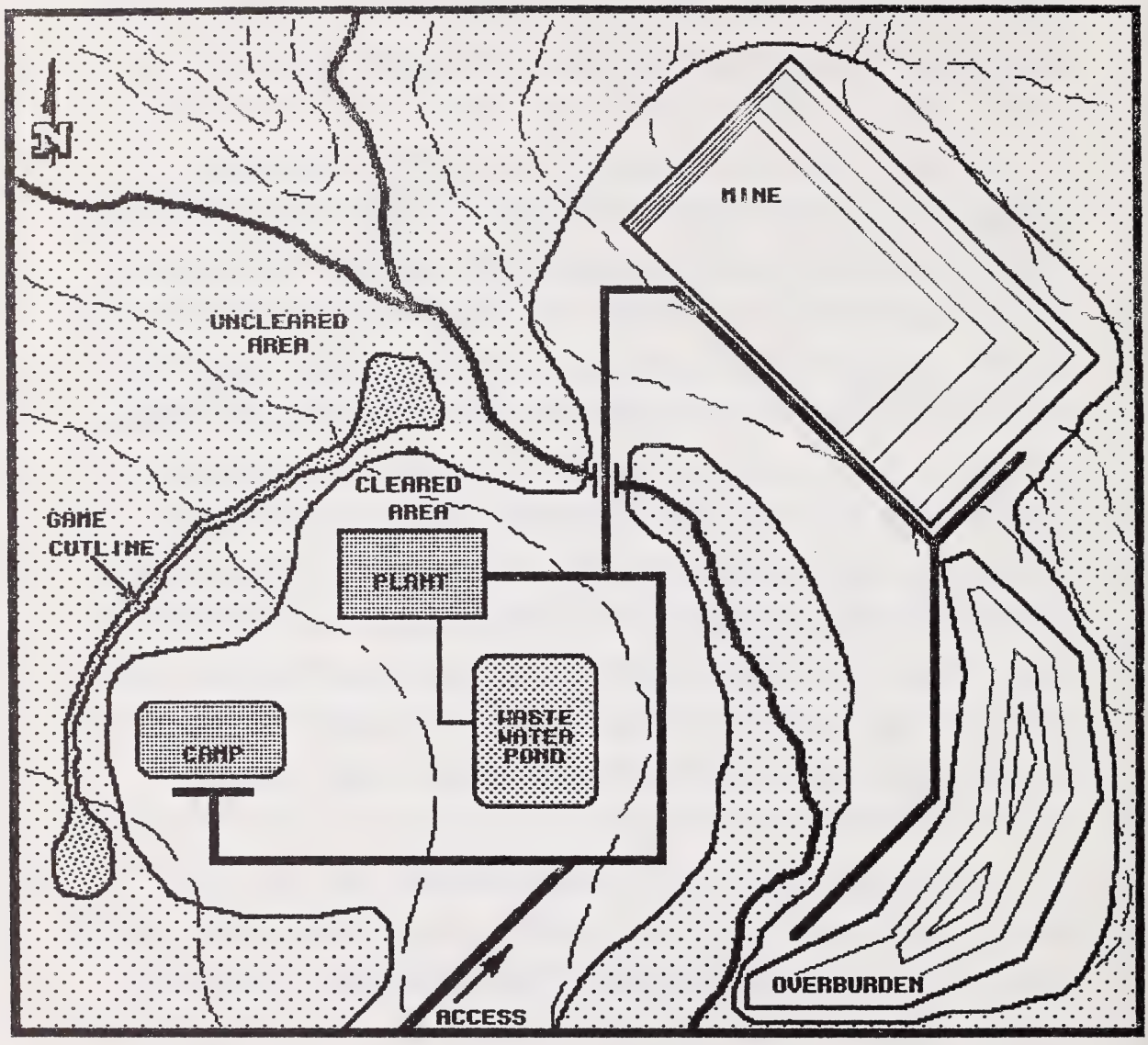


Figure 6. Example of a hypothetical mine site plan in which preplanning has considered a wildlife end use for reclamation and has allowed for wildlife use during operations.

V. CONCLUSIONS

As shown in a number of studies, it is possible and often desirable to integrate wildlife end uses with other land use objectives. Reclamation of wildlife habitat, whether it is a primary or secondary objective, can provide a reasonable, economic alternative for reclamation programs. In addition, reclamation to wildlife habitat often lends a degree of flexibility to the reclamation program. From past experience, however, if reclamation methods for wildlife are to be effective and economic, they must be included at the initial reclamation planning stages or, ideally, in the preplanning stage of the site development plan.

There are numerous opportunities to incorporate wildlife end uses in reclamation areas, but until recently, many of these opportunities have been ignored. If wildlife end uses are to become a more common alternative in reclamation, reclamation planners need to consider more seriously the option for reclamation for wildlife habitat and the methods available to successfully reclaim areas for wildlife. Wildlife managers must work in close cooperation with reclamation planners to design landscapes that are attractive and useable by wildlife. Such landscapes are likely to provide secondary benefits of recreational land uses.

VI. LITERATURE CITED

Baldassarre, G.A., and L.E. Nauman. 1981. Factors affecting waterfowl use and production on man-made flowages in central Wisconsin. Trans. Wisc. Sci., Arts and Letters. 69:4-14

Barr Engineering Co. and J.P. Borovsky. 1980. Enhancement of fish and wildlife resources in reclamation of hard rock mineral lands in the upper Mid-west: A guidelines manual. U.S. Fish Wildl. Serv. Contract No. 14-16-0009-79-107. 123 p.

Brenner, F.J., R.B. Kelly, and J. Kelly. 1980. Mammalian community characteristics of surface mine lands in Pennsylvania. Environ. Manage. 6:241-249.

Canadian Wildlife Service. 1981. Wildlife habitat: a handbook for Canada's prairies and parklands. Environment Canada Publication, Catalogue No. CW66-51/1981E. 51 p.

Childress D.A., and R.L. Eng. 1979. Dust abatement project with wildlife enhancement on Canyon Ferry Reservoir, Montana. Pages 282-288. In: G.A. Swanson (tech. coord.). The mitigation symposium: a national workshop on mitigating losses of fish and wildlife habitats. Gen. Tech. Rep. RM-65, Rocky Mountain For. and Range Exp. Station, Fort Collins. 696 p.

Davis, J.W., G.A. Goodwin, and R.A. Ockenfels. 1983. Snag habitat management: proceedings of a symposium. June 1983, Northern Arizona University. Rocky Mountian Forest and Range Experiment Station, Forest Service, U.S. Dept. of Agriculture. U.S.D.A. Forest Serv. General Tech. Report RM-99. 226 p.

Dickson, K.L., and D. Vance. 1981. Revegetating surface mined lands for wildlife in Texas and Oklahoma. U.S. Fish Wildl. Serv. Contract No. 14-16-0009-80-045. 121 p.

Duebbert, H.F., E.T. Jacobson, K.F. Higgins, and E.B. Podoll. 1981. Establishment of seeded grasslands for wildlife habitat in the prairie pothole region. U.S. Dep. Interior, Fish Wildl. Serv. Spec. Sci. Wildlife Report No. 234. 21 p.

Elliot, C.L., and J.D. McKendrick. 1982. Stripmine reclamation and wildlife in Alaska. Agroborealis 14:4-6.

Filion, F.L., S.W. James, J.L. Ducharme, W. Pepper, R. Reid, P. Boxall, and D. Teillet. 1983. The importance of wildlife to Canadians: highlights of the 1981 National survey. Min. Supply and Services Canada. Cat. No. CW66-62/1983E. 40 p.

Giron, B.A. 1981. Wildlife uses of man-made wetlands in the prairie pothole region: a selected annotated bibliography. S. Dakota Coop. Wildl. Res. Unit. Tech. Bull. No. 2. 23 p.

Hansen, L.P., and J.E. Warnock. 1979. Responses of two species of Peromyscus to vegetational succession on land strip-mined for coal. Am. Midl. Nat. 100:416-423.

Hardy and Associates (1978) Ltd. 1982. Development of wildlife habitat in conjunction with construction projects. Draft report. Environ. Protect. Service, Environ. Canada. Project G-0028.

Harrison, G. 1984. The establishment and maintenance of herbaceous cover on distrubance sites in the National Parks. Proceedings of the 1984 Reclamation Research Technical Advisory Committee Workshop: Revegetation Methods for the Mountains and Foothills (in press). Alberta Land Conservation and Reclamation Council. Edmonton, Alberta.

Hurst, G.A., and R.C. Warren. 1981. Enhancing white-tailed deer habitat of pine plantations by intensive management. Miss. Agric. Forest. Expt. Station. Tech. Bull. No. 107. 7 p.

Karr, J.R. 1968. Habitat and avian diversity on strip-mined land in east central Illinois. Condor 70:348-357.

Knott, R., and D.E. Samuel. 1982. White-tailed deer movement and distribution about surface coal mines in West Virginia, U.S.A. Minerals and the Environment. 4:17-25.

Markum, B. 1980. Integration of wildlife and agricultural values in the post-mining landscape. RRTAC Report 80-14-MAR. Alberta Land Conservation and Reclamation Council. Edmonton, Alberta.

Marshall, I.B. 1983. Mining, land use and the environment. II. A review of mine reclamation activities in Canada. Environment Canada, Lands Directorate. En 73-1/23E. 288 p.

Millson, R., and T. Bondy. 1984. Revegation planning for wildlife and forestry. Proceedings of the 1984 Reclamation Research Technical Advisory Committee Workshop: Revegetation Methods for the Mountains and Foothills (in press). Alberta Land Conservation and Reclamation Council. Edmonton, Alberta.

Mumford, R.E., and W.G. Bramble. 1969. Small mammals on surface-mined land in southeast Indiana. In: R.J. Hutnick and G. Davis (eds.). Ecology and reclamation of devastated land. Pages 369-376.

Olson, R.A. 1981. Wetland vegatation, environmental factors, and their interaction in strip mine ponds, stockdams, and natural wetlands. U.S. Dept. of Agriculture, Forest Service. General Tech. Rep. RM-85. 19 p.

Proctor, B.R., R.W. Thompson, J.E. Bunin, K.W. Fucik, G.R. Tamm and E.G. Wolf. 1983. Practices for protecting and enhancing fish and wildlife on coal surface-mined land in the Powder River - Fort Union Region. Western Energy and Land Use Team, U.S. Fish and Wildlife Service, Fort Collins, Colorado. FWS/OBS - 83/10. 246 p.

Rickard, W.H., R.E. Fitzner, and C.E. Cushing. 1981. Biological colonization of an industrial pond: Status after two decades. Environ. Conserv. 8:241-248.

Sly, C.R. 1976. Small mammal succession on strip-mined land in Vigo County, Indianna. Am. Midl. Nat. 95:257-266.

Utah State University. 1978. Rehabilitation of western wildlife habitat: a review. U.S. Dep. Interior, Fish Wildl. Serv. FWS/OBS-78/86.

Van Waggoner, K. 1978. The effect of lignite mining and reclamation on small mammal populations in Texas. In: Surface Mining and Fish/Wildlife Needs in the eastern United States. U.S. Fish Wildl. Serv. FWS/OBS-78/81. Pages 256-266.

Verts, B.J. 1959. Notes on the ecology of mammals of a strip-mined area in southern Illinois. Trans. Ill. State Acad. Sci. 52:134-139.

Vogel, W.G. 1981. A guide for revegetating coal minesoils in the eastern United States. U.S. Dept. of Agriculture, Forest Service. General Technical Report NE-68. 190 p.

Voight, J.R., and D.C. Glenn-Lewin. 1979. Strip mining, Peromyscus, and other small mammals in southern Iowa. Proc. Iowa Acad. Sci. 86:133-136.

Whitmore, R.C. 1980. Reclaimed surface mines as avian habitat islands in the eastern forest. Amer. Birds 34:13-14.

LIST OF PARTICIPANTS

1. ACOTT, G.
Cardinal River Coals Ltd.
P.O. Box 2570
HINTON, Alberta
TOE 1CO

2. BEDDOME, D.
Alberta Environment
Box 2924
EDSON, Alberta
TOE OPO

3. BENSON, J.E.
Deputy Chairman
Land Conservation & Reclamation Council
9920 - 108th Street
EDMONTON, Alberta
T5K 2M4

4. BLACKMORE, Dan
Alberta Forest Service
9915 - 108th Street
EDMONTON, Alberta
T5K 2C9

5. BONDY, J.
Alberta Energy & Natural Resources
6th Floor, Bramalea Building
9920 - 108th Street
EDMONTON, Alberta
T5K 2M4

6. CAMPBELL, James, A.
Research Management
Alberta Environment
9820 - 106th Street
EDMONTON, Alberta
T5K 2J6

7. CRANE, Ken
Senior Planning Coordinator
Luscar Limited
800 Royal Trust Tower
EDMONTON, Alberta
T5J 2Z2

8. DERMOTT, C.A.
Alberta Forest Service
9920 - 108th Street
EDMONTON, Alberta
T5K 2M4

9. FEDKENHEUER, A.W.
Nova an Alberta Corporation
Post Office Box 2535
Postal Station "M"
CALGARY, Alberta
T2P 2N6

10. FERDINAND, S.
Alberta Forest Service
9915 - 108th Street
EDMONTON, Alberta
T5K 2C9

11. FERSTER, R.F.
Environmental Planner
Luscar Ltd.
800 Royal Trust Tower
EDMONTON, Alberta
T5J 2Z2

12. FESSENDEN, R.J.
Alberta Research Council
10030 - 107th Street
EDMONTON, Alberta
T5J 3E5

13. GARDINER, R.J.
Fording Coal Ltd.
P.O. Box 100
ELKFORD, B.C.
VOB 1HO

14. GREEN, Jeff
Wildlife Biologist
LGL Limited
202, 10110 - 124th Street
EDMONTON, Alberta
T5N 1P6

List of Participants Cont'd

15. HARRISON, Gail
Research Associate
Parks Canada
P.O. Box 2989
Postal Station "M"
CALGARY, Alberta
T2P 3H8

16. HERMESH, R.
Alberta Environmental Centre
Bag 4000
VEGREVILLE, Alberta
TOB 4L0

17. HUDSON, Brian
Alberta Energy & Natural Resources
Public Lands
4th Floor, Petroleum Plaza
9915 - 108th Street
EDMONTON, Alberta
T5K 2C9

18. ISLAM, Rafique
Soil Scientist
Alberta Forest Service
9th Floor, 9920 - 108th Street
EDMONTON, Alberta
T5K 2C9

19. JOHNSON, R.S.
Alberta Environmental Centre
Box 4000
VEGREVILLE, Alberta
TOB 4L0

20. JOHNSON, Terry
Alberta Environment
Reclamation Council
Box 2924
EDSON, Alberta

21. KEMP, J.
Prism Environmental Management
Consultants
157 Tudor Lane
EDMONTON, Alberta
T6J 3T5

22. KENNEDY, A.
Environmental Biologist
Esso Minerals Canada
237 - 4th Avenue S.W.
CALGARY, Alberta
T2P 0H6

23. KING, Paul
Reclamation & Reforestation
Alberta Forest Service
9th Floor, 9920 - 108th Street
EDMONTON, Alberta
T6K 2M4

24. KITTLESON, Dean
Environmental Planner
Crows Nest Resources Limited
Eau Claire Place
525 - 3rd Avenue S.W.
CALGARY, Alberta
T2P 2M7

25. LANT, J.
Manager, Environment
Line Creek
Crows Nest Resources Limited
Eau Claire Place
525 - 3rd Avenue S.W.
CALGARY, Alberta
T2P 2M7

26. LLOYD, David
Reclamation Coordinator
Alberta Energy & Natural Resource
Public Lands Division
South Tower Petroleum Plaza
9915 - 108th Street
EDMONTON, Alberta
T5K 2C9

List of Participants Cont'd

27. MACYK, Terry
Research Officer
Alberta Research Council
6th Floor, Terrace Plaza
4445 Calgary Trail South
EDMONTON, Alberta
T6H 5R7

28. McANDREWS, Greg
District Supervisor
Public Lands
826, 620 - 7th Avenue S.W.
CALGARY, Alberta
T2P OT8

29. MIDDLETON, R.
Landscape Architect
9th Floor, Oxbridge Place
9820 - 106th Street
EDMONTON, Alberta

30. MILLSON, Ron
Habitat Protection Biologist
Alberta Energy & Natural Resources
Fish & Wildlife
2nd Floor, 9920 - 108th Street
EDMONTON, Alberta

31. MORAN Stephan R.
Alberta Research Council
Alberta Geological Survey
3rd Floor, Terrace Plaza
4445 Calgary Trail
EDMONTON, Alberta
T6H 5R7

32. NATSUKOSHI, Karen
Environmentalist
Manalta Coal Ltd.
Box 2880
CALGARY, Alberta
T2P 2M7

33. PATTERSON, D.B.
Alberta Environment
3rd Floor, Oxbridge Place
9820 - 106th Street
EDMONTON, Alberta
T5K 2J6

34. POWTER, C.
Research Assistant
Research Management
11th Floor
Standard Life Building
10405 Jasper Avenue
EDMONTON, Alberta

35. RUSSELL, W.B.
1301, 8715 - 104th Street
EDMONTON, Alberta
T6E 4G7

36. SKIRROW, Bruce
Reclamation Engineer
Smokey River Coals Ltd.
Box 2000
GRANDE CACHE, Alberta
TOE OYO

37. TAKYI, S.K.
Alberta Forest Service
9th Floor, 9920 - 108th Street
EDMONTON, Alberta
T5K 2M4

38. TOWNSEND, Don
Line Creek Coal Ltd.
P.O. Box 2003
SPARWOOD, B.C.
VOB 2GO

List of Participants Cont'd

39. WALKER, D.G.
Department of Forestry
University of Alberta
EDMONTON, Alberta
T6G 2P5

40. WINNICK, Loren J.
Industrial Activities Coordinator
Alberta Energy & Natural Resources
EDMONTON, Alberta
T5X 3G8

41. YONGE, Keith
Assistant Director
Canadian Wildlife Service
Environment Canada
Western & Northern Region
1000, 9942 - 108th Street
EDMONTON, Alberta
T5K 2J5

42. ZIEMKIEWICZ, Paul F.
Chairman Reclamation Research
Technical Advisory Committee
Alberta Energy & Natural Resources
2nd Floor, Pacific Plaza
10909 Jasper Avenue
EDMONTON, Alberta
T6J 3M8

43. ZROBACK, Rick
Gregg River Resources Ltd.
Bag Service 5000
HINTON, Alberta
TOE 1BO

RRTAC WORKSHOP
REVEGETATION METHODS
FOR THE
MOUNTAINS AND FOOTHILLS

DATE: April 30 - May 1, 1984

PLACE: 6th Floor Training Room
9945 - 108th Street
North Tower Petroleum Plaza
EDMONTON, Alberta

AGENDA

Day 1 - April 30

Time	Presentation
8:30 - 8:40	Introduction - P.F. Ziemkiewicz
8:40 - 9:00	1. Performance of Native Grasses and cultivated Legumes and Grasses on land disturbances in the Eastern Slopes - S.K. Takyi, R. Islam
9:00 - 9:20	2. Bow Valley Parkway Revegetation Trials, Banff National Park - D.G. Walker, G. Harrison
9:20 - 9:50	3. Species selection in the Sub-Alpine and Alpine - P.F. Ziemkiewicz
9:50 - 10:05	Discussion
10:05 - 10:50	Coffee Break
10:50 - 11:10	4. 1) Establishment of Non-woody Vegetative Cover at No. 8 and No. 9 mines, Grande Cache, Alberta - T. Macyk and B. Skirrow
10:10 - 11:30	2) Establishment of Trees and Shrubs at No. 8 Mine, Grande Cache, Alberta - T. Macyk and B. Skirrow
11:30 - 11:50	5. Operational Reclamation Methods of Plant Cover Establishment on a severe site in the Sub-Alpine - S.K. Takyi
11:50 - 12:05	Discussion
12:05 - 1:35	Lunch
1:35 - 1:55	6. Natural Invasion of Old Mining Disturbances - W.B. Russell
1:55 - 2:15	7. The role of Topsoil, Fertilizers and Companion Crops in Revegetation of severe sites in the Sub-Alpine - S.K. Takyi
2:15 - 3:00	Coffee Break

3:00 - 3:20	8.	The Establishment and Maintenance of Herbacious Cover on Disturbance Sites in the National Parks - G. Harrison
3:20 - 3:40	9.	Rehabilitation of Oil and Salt Water Spill Sites - D. Blackmore
3:40 - 4:10		Discussion

Day 2 - May 1

8:30 - 8:50	10.	Pre-germination Treatments for selected Woody Plant Species Native to the Eastern Slopes - P. King, G. Grainger, A. Straka
8:50 - 9:10	11.	Tree Establishment and Growth Based on Judy Creek Test Mine Reclamation Studies - A. Kennedy
9:10 - 9:30	12.	Operational Site Preparation and Experience in Reforestation of Cutovers in the Foothills - S. Ferdinand
9:30 - 9:45		Discussion
9:45 - 10:30		Coffee Break
10:30 - 10:50	13.	Coal Valley Mine Reclamation Trends. The Past Guiding the Present - K.G. Crane and R. Ferster
10:50 - 11:10	14.	Methodology and Initial Results of the Bryan Mountain Reclamation Test Plots - D. Kittleson
11:10 - 11:30	15.	Woody Species Demonstrations and Trials on Disturbances in the Eastern Slopes - P. King
11:30 - 11:45		Discussion
11:45 - 1:15		Lunch
1:15 - 1:35	16.	Current Research on Seedling Growth at Obed Marsh - T.A.B. Adamson
1:35 - 1:55	17.	Revegetation Planning for Wildlife and Forestry - R. Millson and T. Bondy
1:55 - 2:15	18.	Techniques for Enhancement of Wildlife Habitat and Criteria for Wildlife End Uses - J. Green
2:15 - 3:00		Coffee Break
3:00 - 3:30		Discussion

N.L.C. - B.N.C.
3 3286 05820888 1